Talk info/notes

Venue: Strange Quark Matter 2013 (SQM)

Title - eRHIC: A Precision Tool for Studying Nuclear Structure.

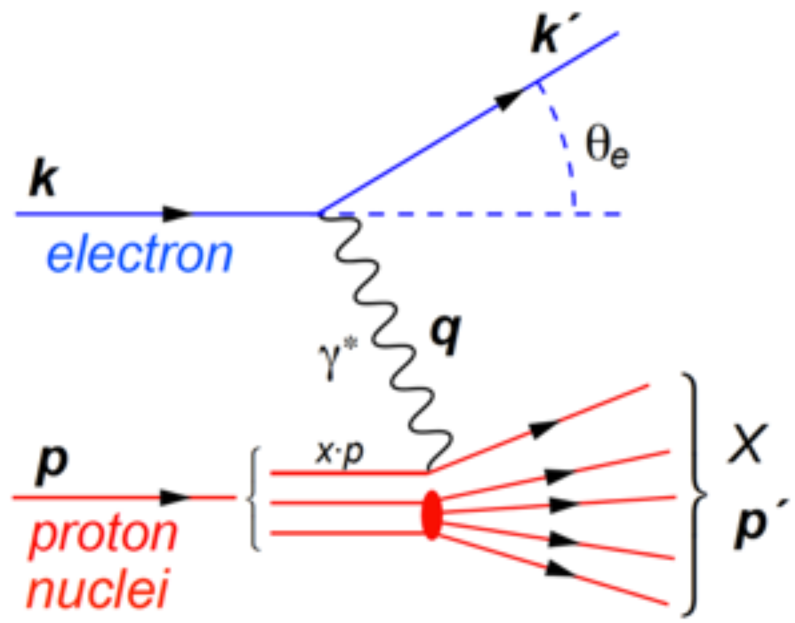
Abstract -

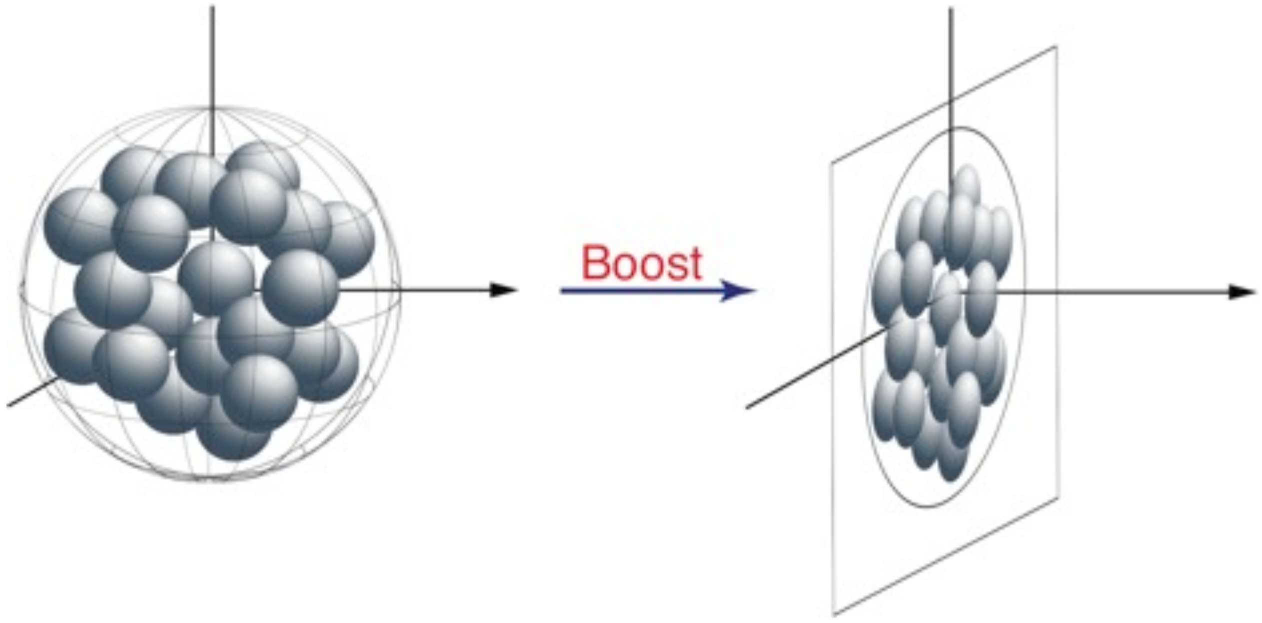
eRHIC is envisaged as a next-generation upgrade to the RHIC facility, involving the addition of a high-intensity, high-energy electron beam, to deliver a broad programme of both nuclear and spin physics.
e+A collisions at eRHIC will answer open questions about the distribution and interactions of gluons within nuclei, something not possible with any existing machine. They will allow precise probing of the nuclear initial state, due to both the absence of the final-state interactions present in nucleus-nucleus collisions, which obscure details of the initial state, and the precise reconstruction of the initial event kinematics afforded by an electron beam. Exclusive diffractive collisions will allow the nuclear gluon distribution to be imaged in detail, while the use of nuclear beams will provide access to the regime of low-x gluon saturation, for which there are presently only tantalising hints. Meanwhile, polarised electron and proton beams will yield unmatched detail in characterising the spin structure of nucleons. I will summarise the features of the eRHIC accelerator itself and some of the key measurements to be made, with a focus on in its e+A physics programme.

20 minutes, including questions. Aiming for 15-17 minutes of actual content, leave the remainder for questions.

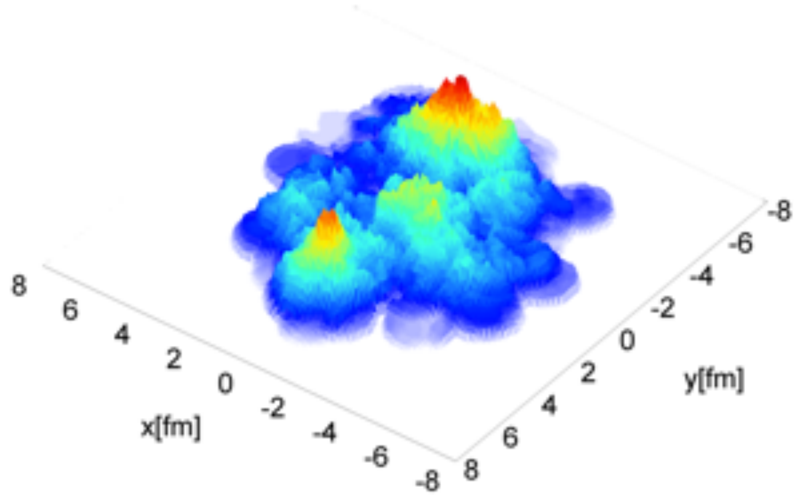
Still working on layout, and needs “bookends” and polishing (DOE/BNL logos and things like that).

Introduction





- eRHIC and DIS overview
- Key eA measurements
- Detector concept
- Machine design



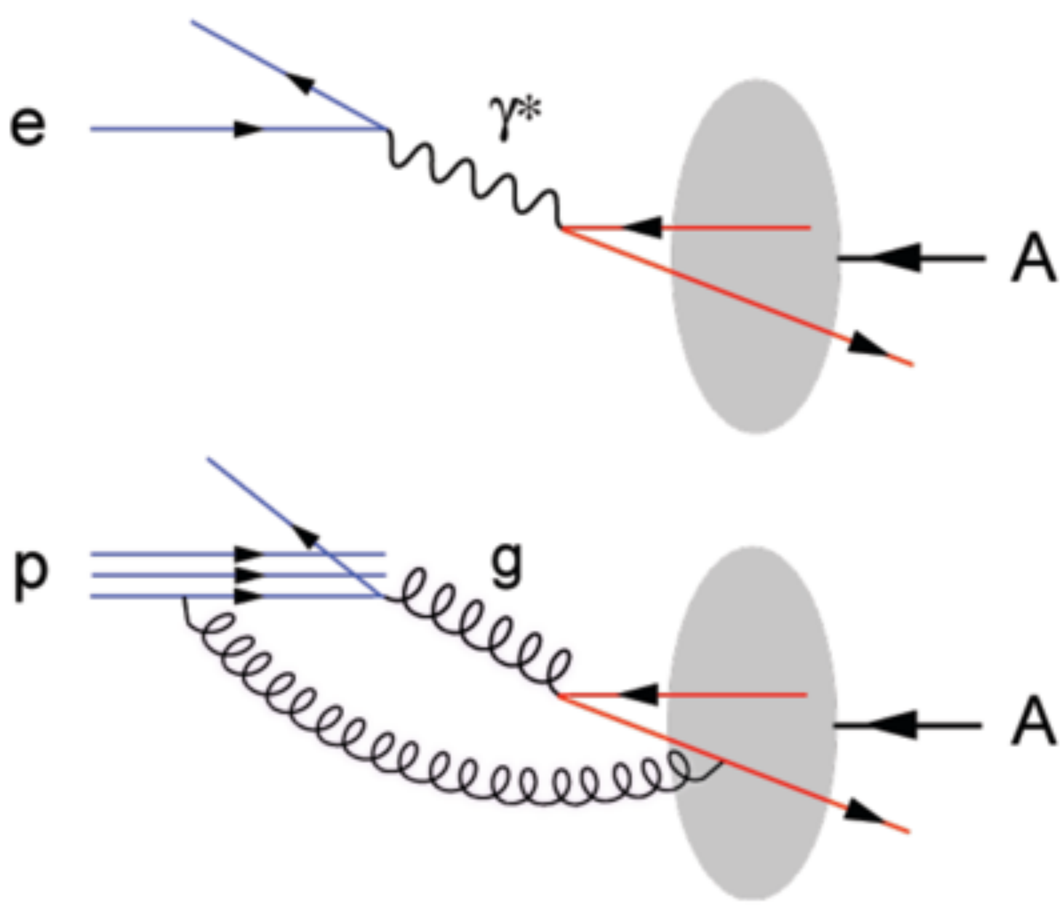
What is eRHIC?

Relativistic **H**eavy **I**on **C**ollider
+
Energy-recovery linac

- Adds **ep** and **eA** capability to RHIC
- Utilises much current investment
- Successor to both RHIC and HERA

Why **e**A collisions?

- RHIC is a successful hadronic machine
  - so why bother with **electrons**?



- Electrons give **three** advantages
  - *Clean*: no “spectator” background
  - *Clear*: distinguish initial/final-state effects
  - *Precise*: direct access to parton-level kinematics via deeply inelastic scattering

(an aside on DIS kinematics)

$$s = (p + k)^2 = 4 \cdot E_p \cdot E_e$$

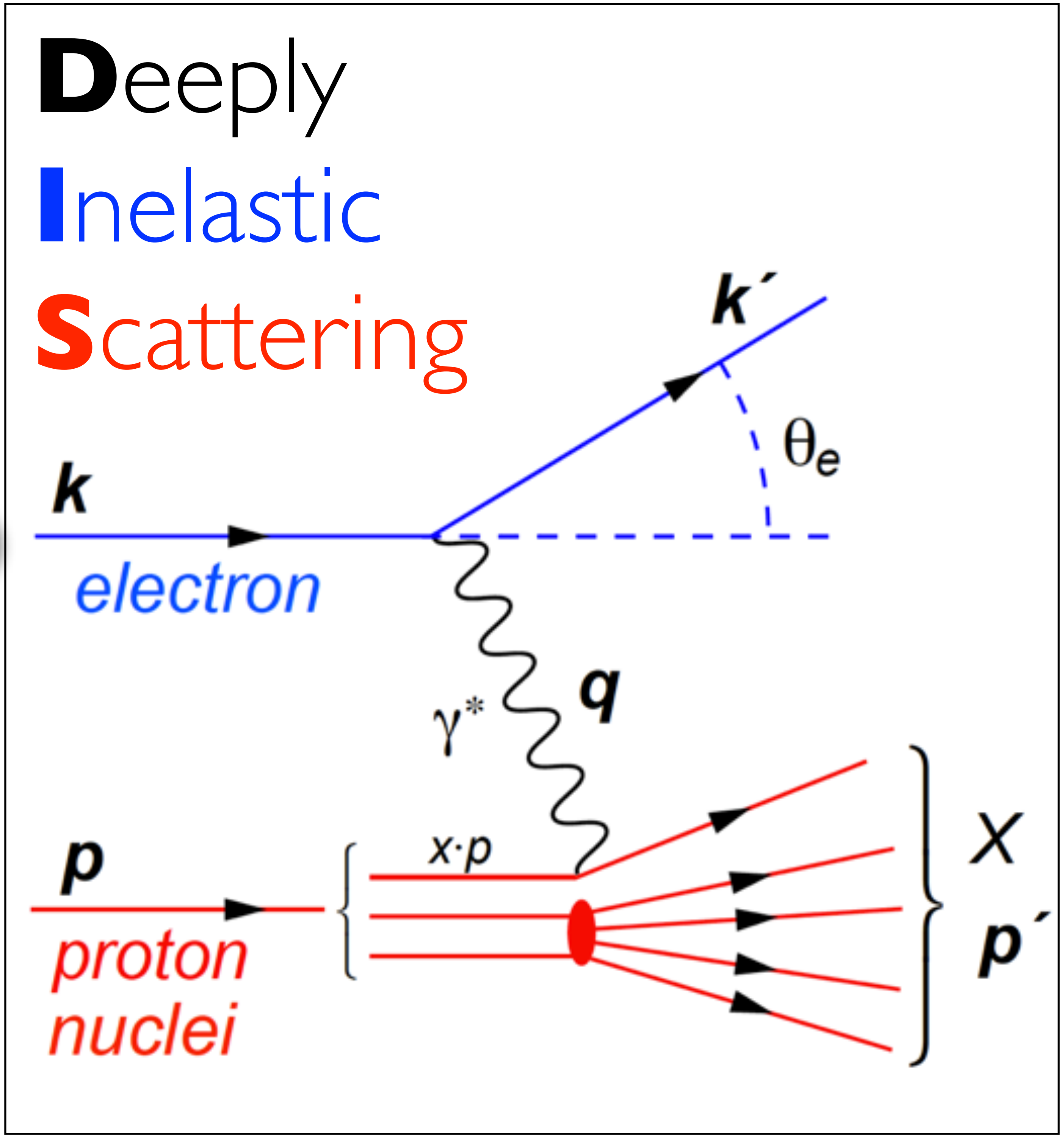
$$Q^2 = -q^2 = -(k - k')^2$$

"resolution"

$$x_B = \frac{Q^2}{2 \cdot p \cdot q}$$

$$y = \frac{q \cdot p}{k \cdot p}$$

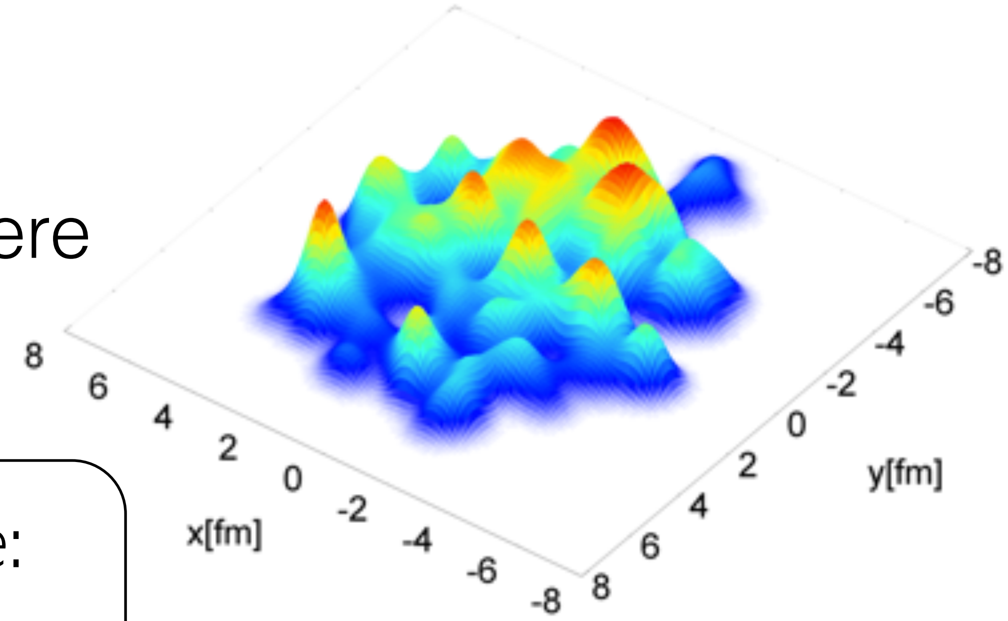
"inelasticity"



- Kinematics **entirely defined** by scattered electron

- eRHIC physics goals
  - impossible to give more than a taste here
  - eA
    - Saturation
    - Imaging
    - Nuclear PDFs
    - Hadronisation in strongly interacting medium
  - ep (not covered here)
    - nucleon imaging (impact parameter dependence)
    - unintegrated PDFs (pT-dependence)
    - spin sum rule (origin of spin-1/2 proton/neutron)

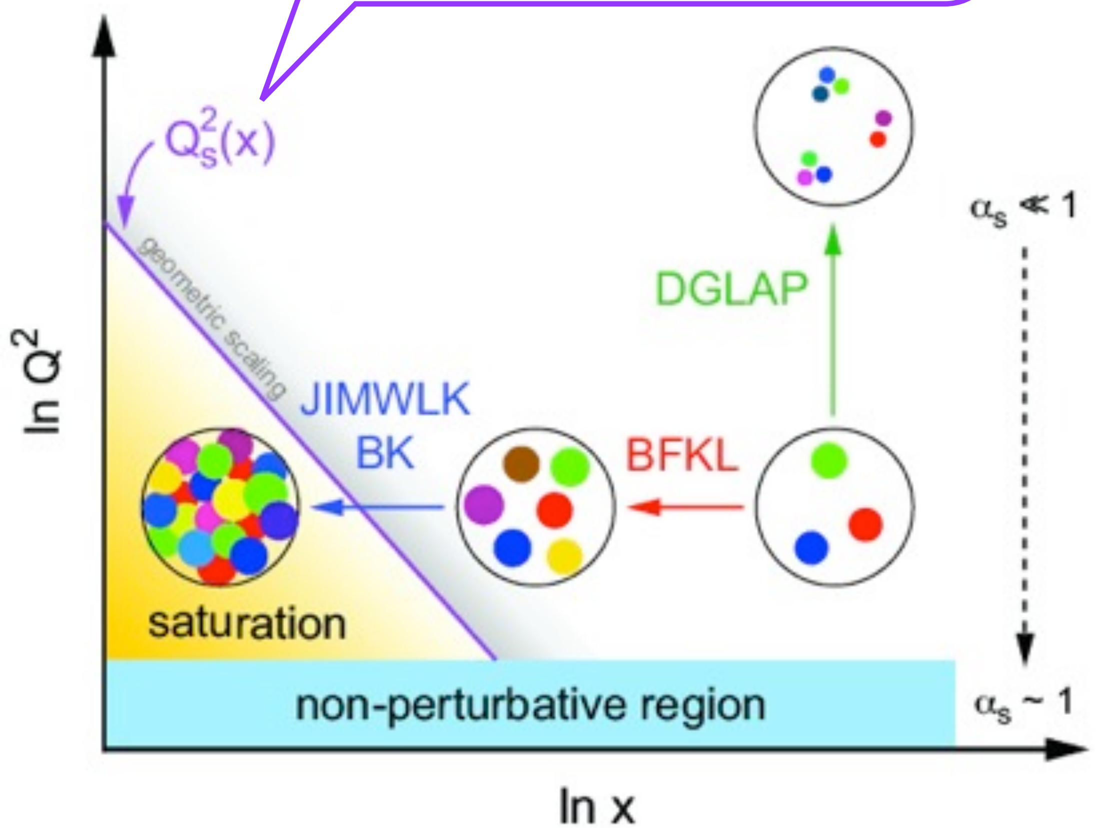
Nuclear initial state: vital to understanding nuclear collisions

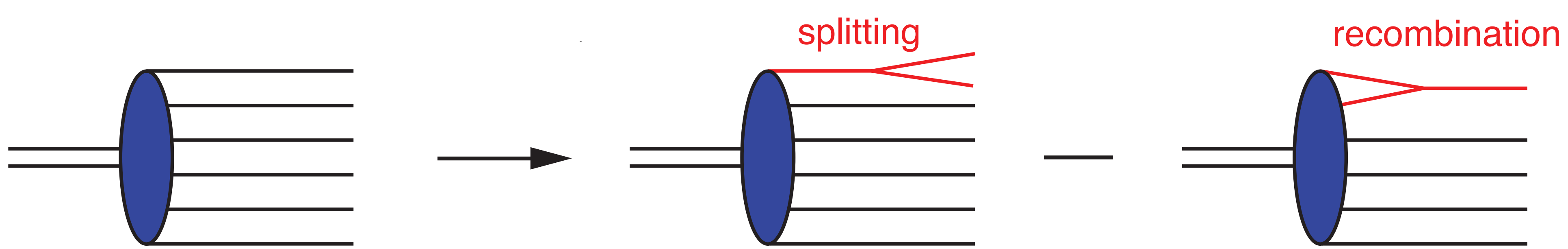


Gluons at small x

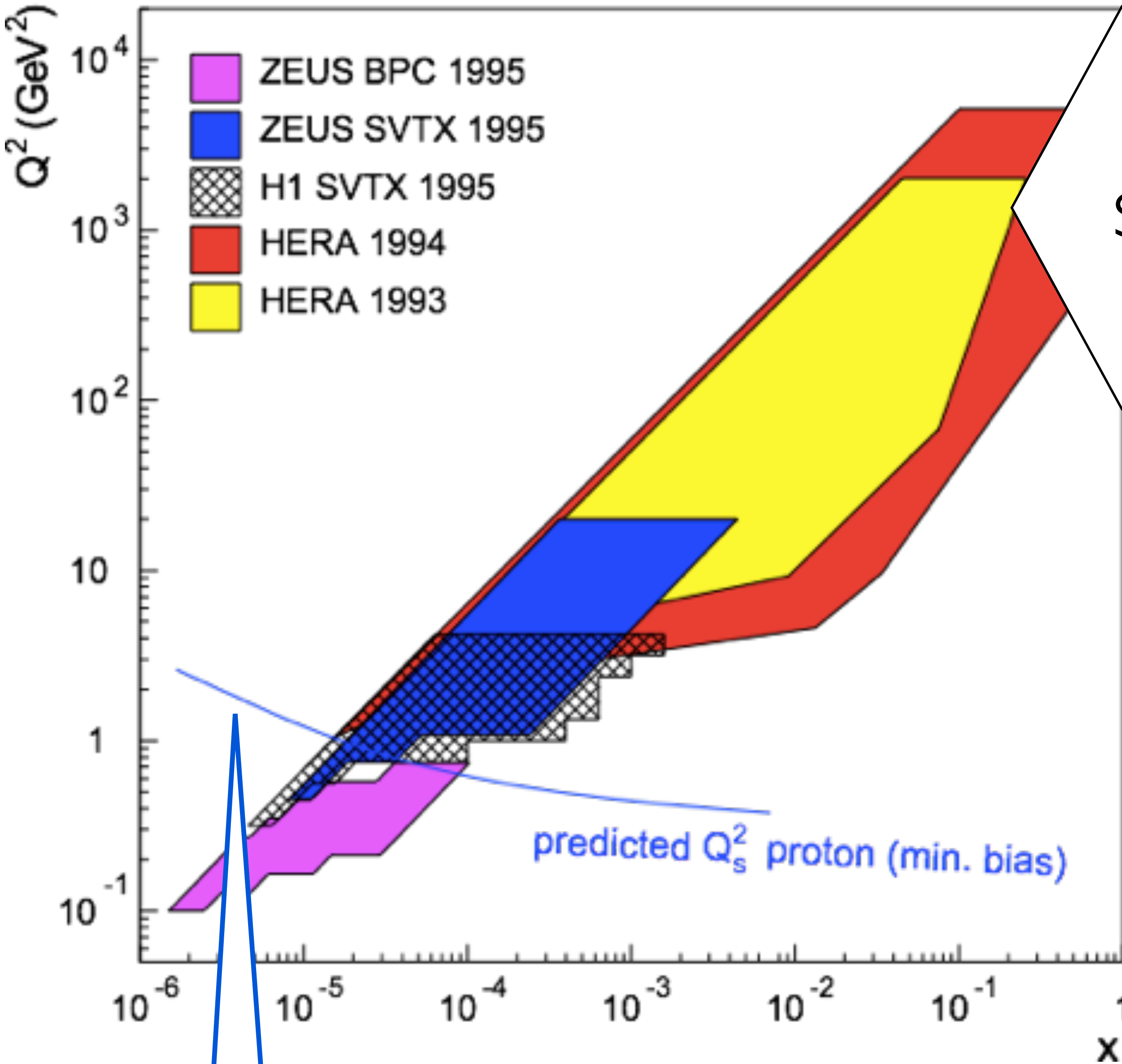
- QCD interaction accounts for 99% of proton mass
  - c.f. 1% Higgs mass of quarks
- Gluon PDFs from DIS show explosive growth at small x
  - must be tamed at some point
- non-linear evolution e.g. BK alternative to DGLAP, BFKL, account for **gluon recombination**

"**Saturation scale**" at which phenomena manifest





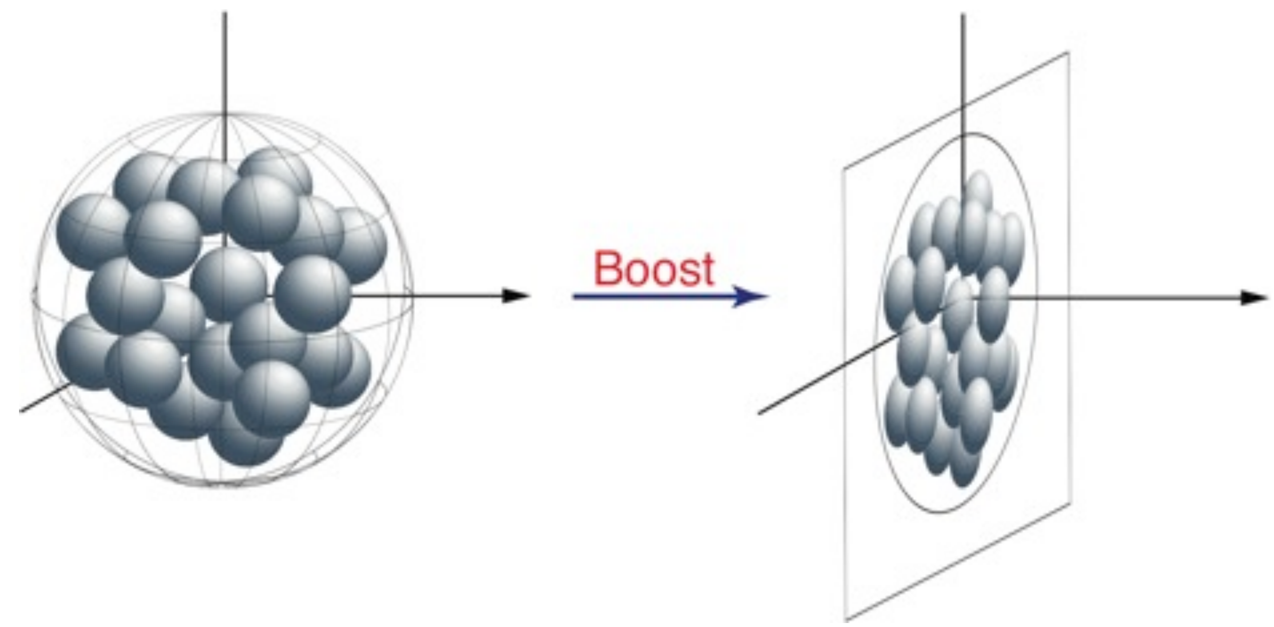
An eA collider: why use nuclei?



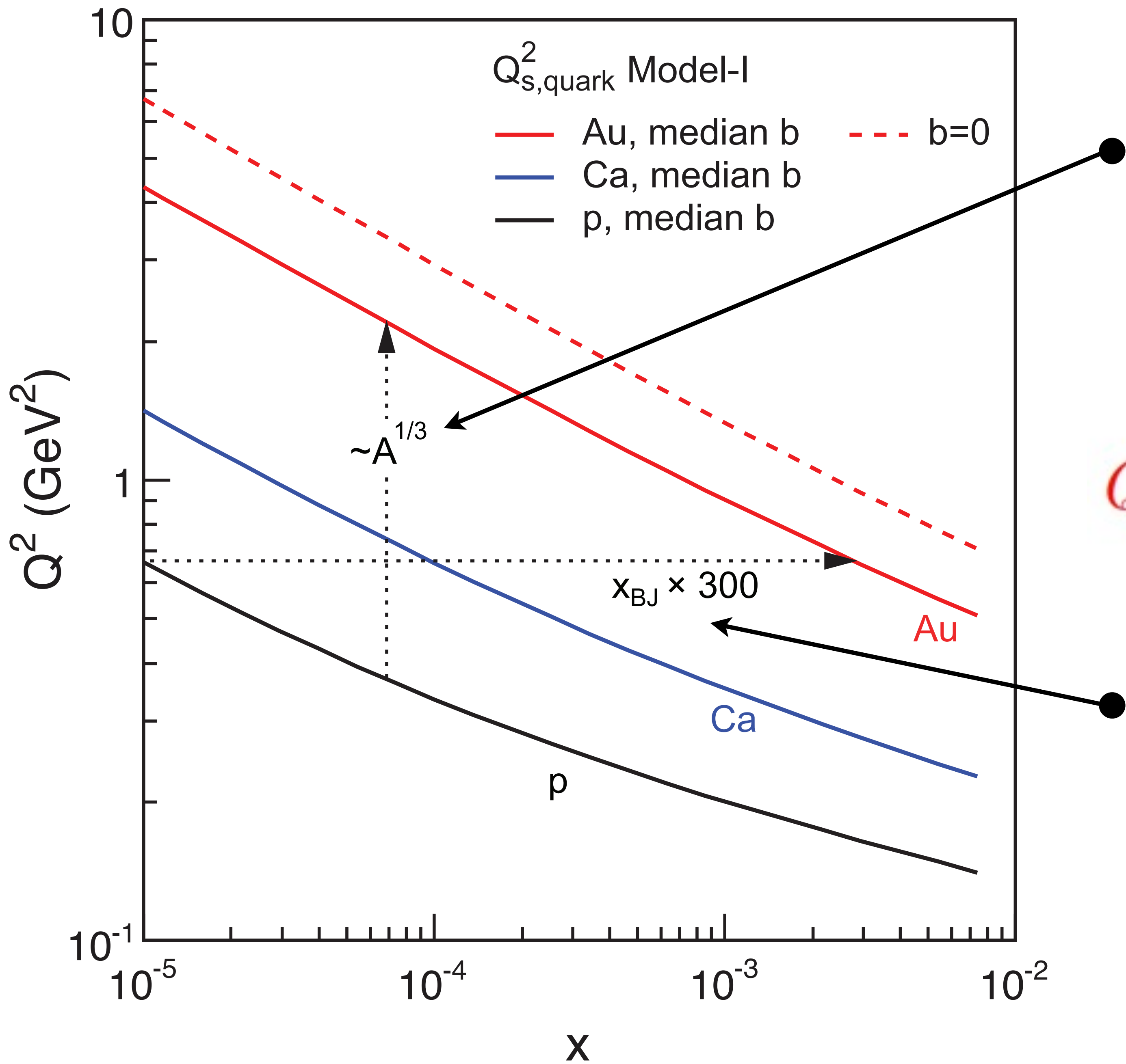
Reaching predicted saturation scale in e-p needs **very low x → 1-2 TeV machine**

Need even lower x than HERA accessed

But...
in a high-E collision gluon density scales ~ nuclear radius



Nuclear amplification



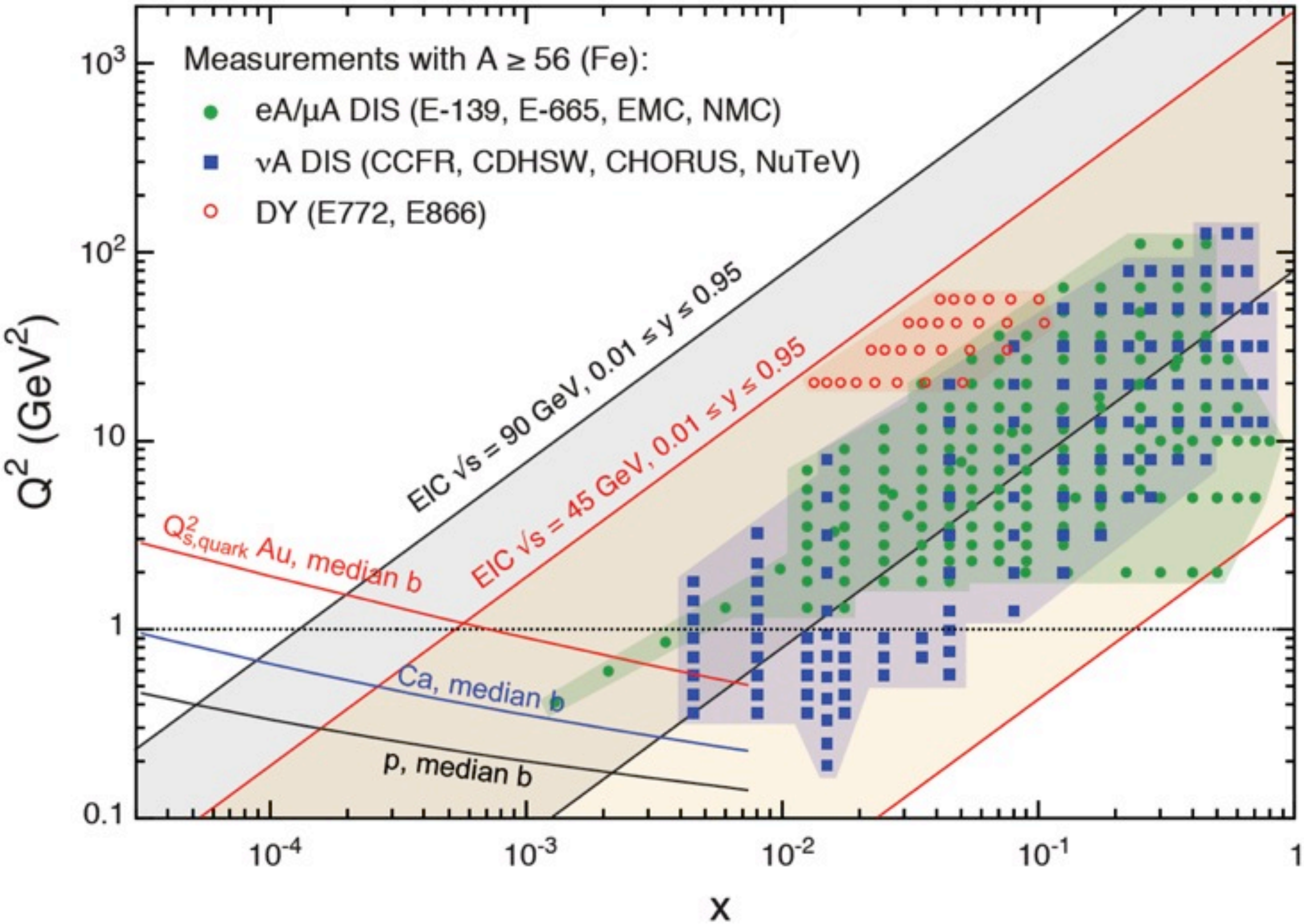
- Nuclear **amplification** of saturation scale

$$Q_s^2(x) \sim A^{1/3}\left(\frac{1}{x}\right)^{\lambda} \sim \left(\frac{A}{x}\right)^{1/3}$$

- "Effective x" is much smaller in nuclei

→Access saturation with ~100 **G**eV eA machine

eRHIC eA kinematics



Extend reach far beyond existing data

- Access saturated regime
- Precise studies of nuclear structure

Key measurements

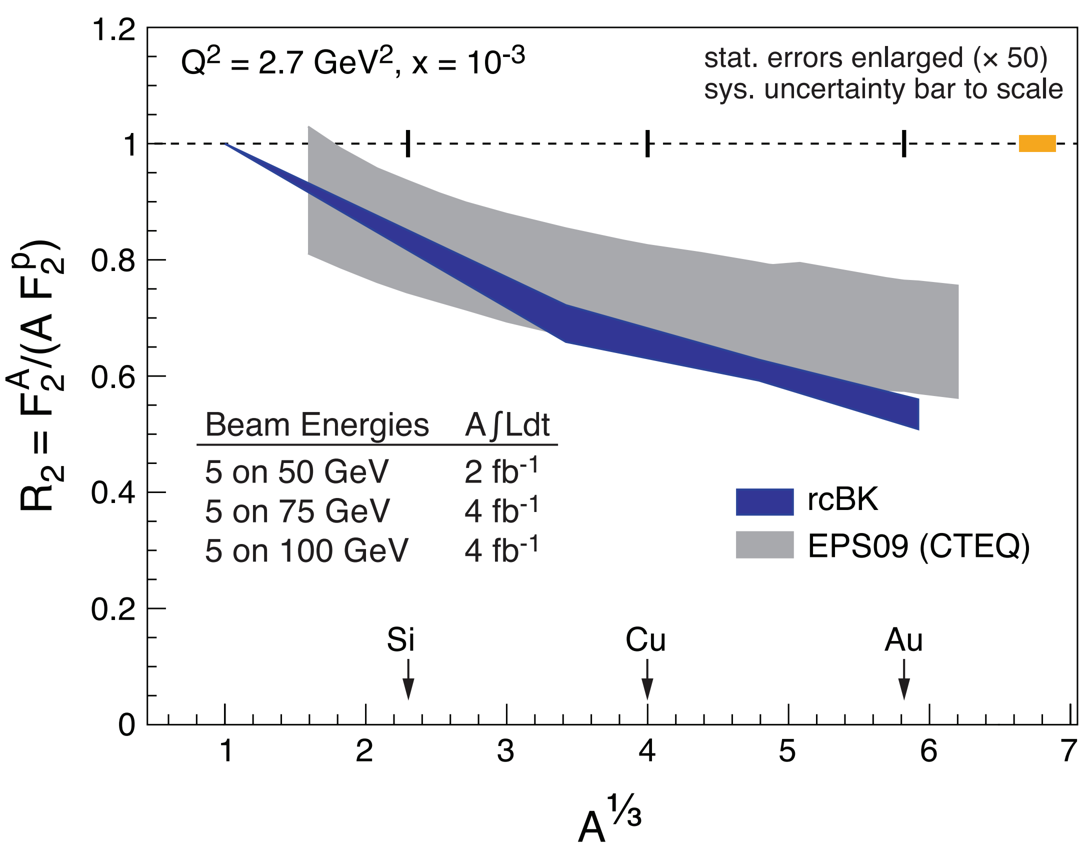
Structure functions

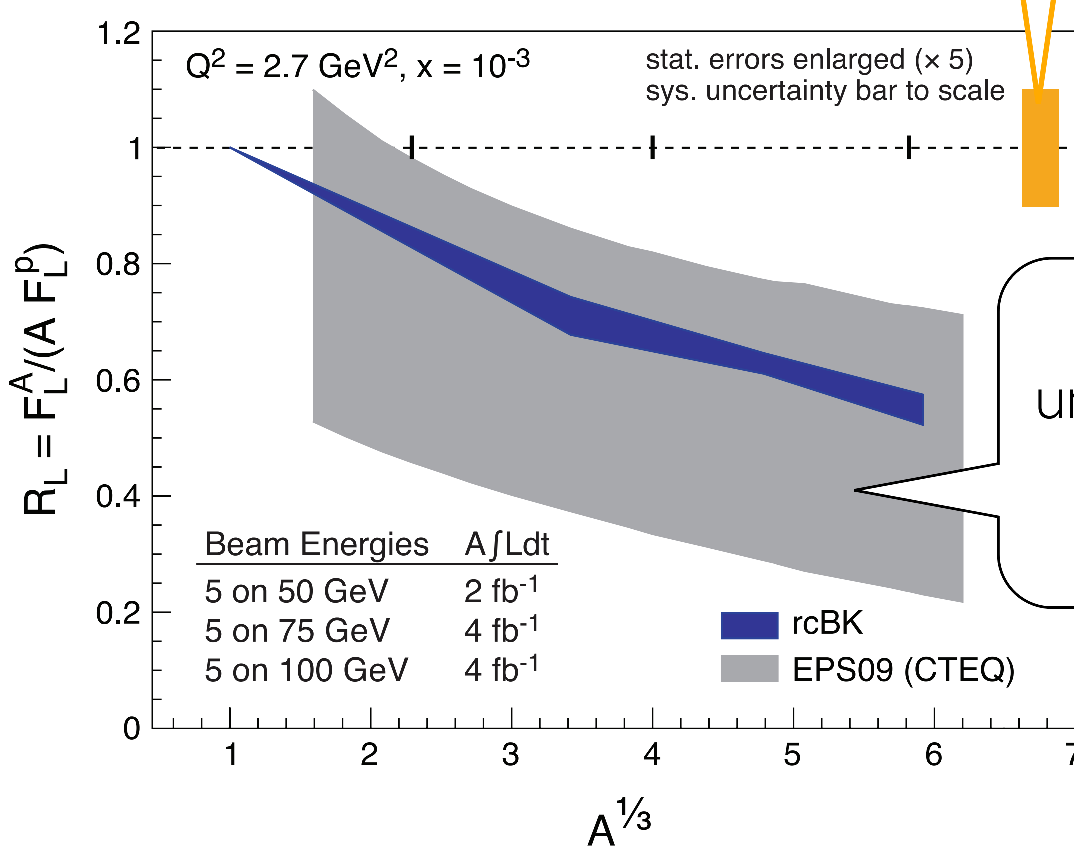
$$\sigma_r = F_2(x, Q^2) - \frac{y^2}{1+(1-y)^2} F_L(x, Q^2)$$

F_2 sensitive to quarks
F_L sensitive to gluons
Separation requires
variable energy

- precision **nuclear PDFs**
- indications of **saturation/non-linearity**

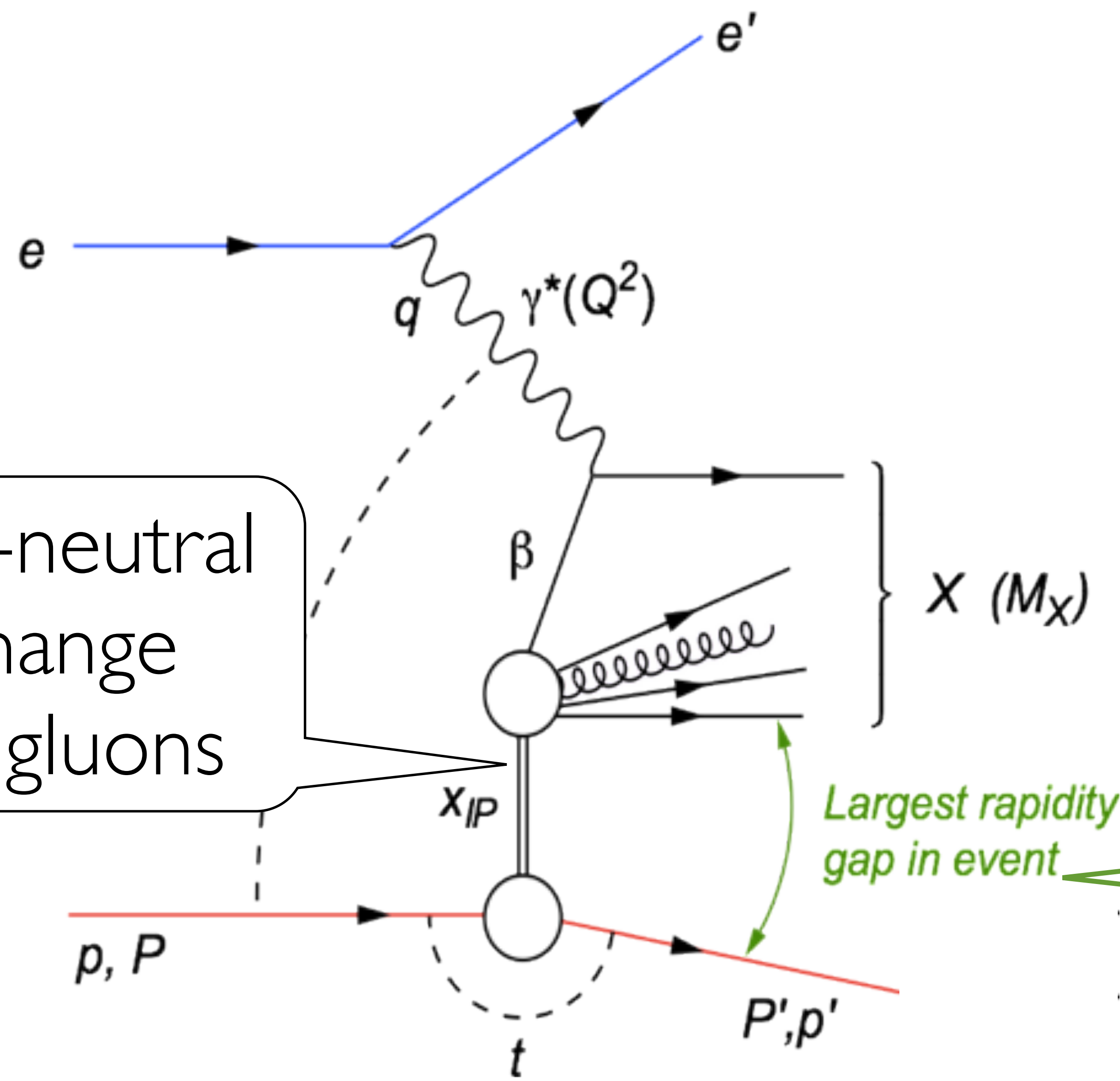
Systematics-dominated





large uncertainties on DGLAP predictions

Diffraction



15% of HERA cross section

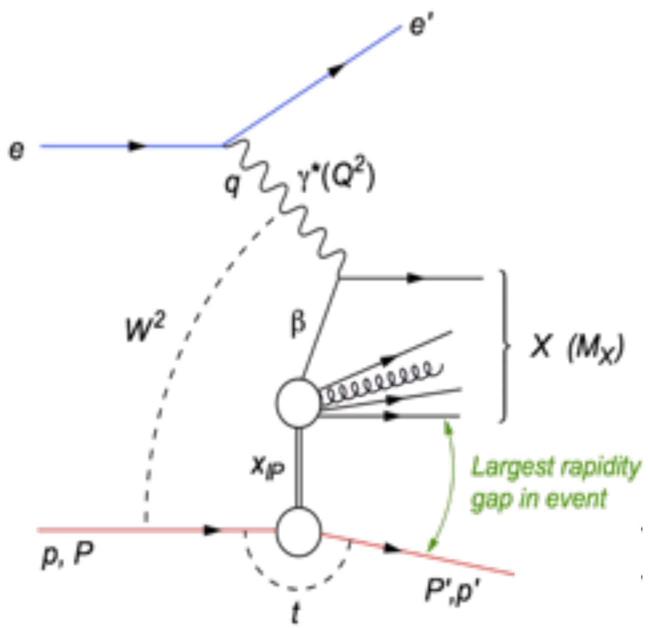
colour-neutral exchange e.g. 2 gluons

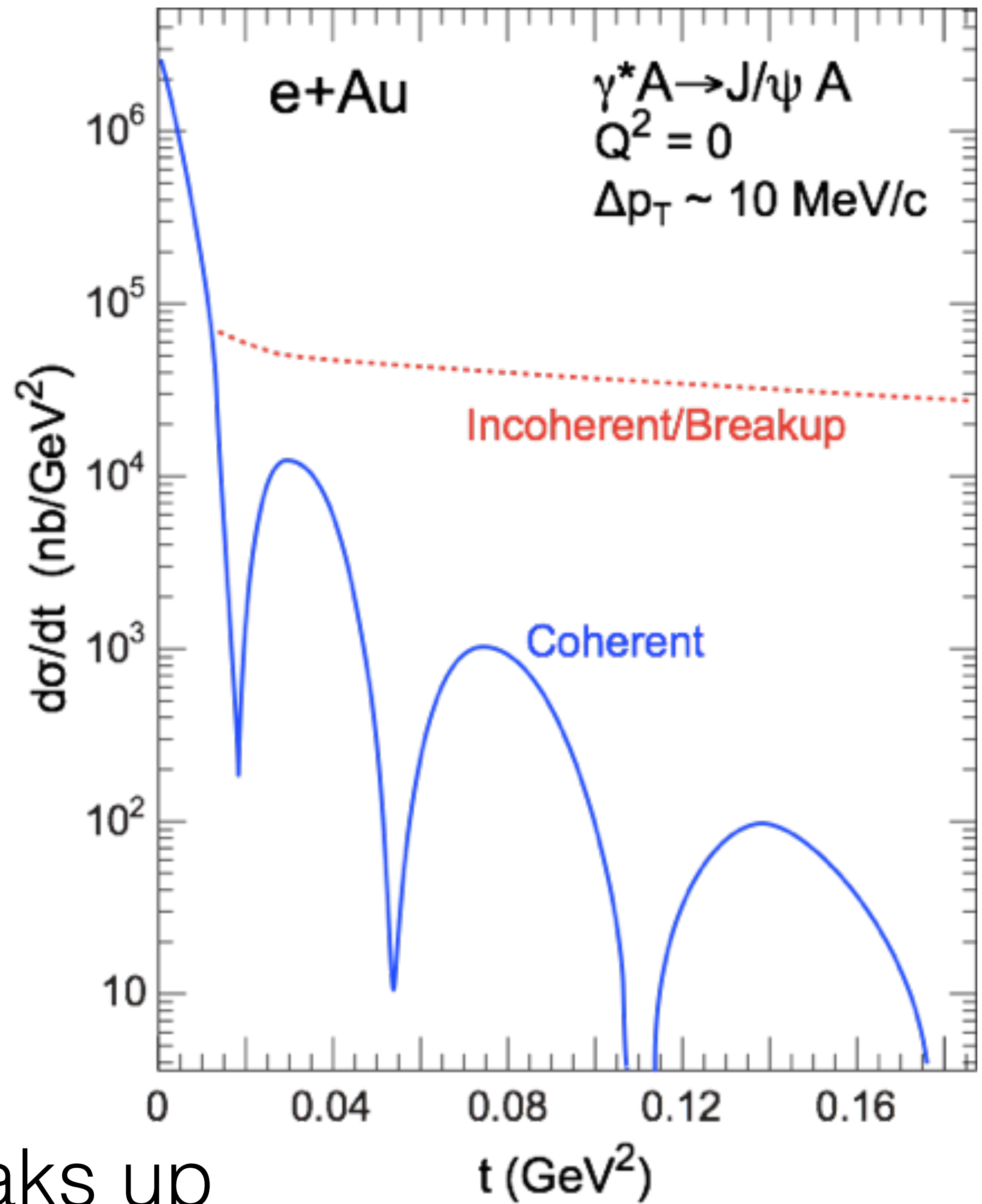
Signature: absence of activity in detector over wide rapidity

Measure additional variable: 4-momentum transfer $t = p - p`$

Ideal for studying gluons:
$\boldsymbol{\sigma} \sim g(x, Q^2)^{\mathbf{2}}$

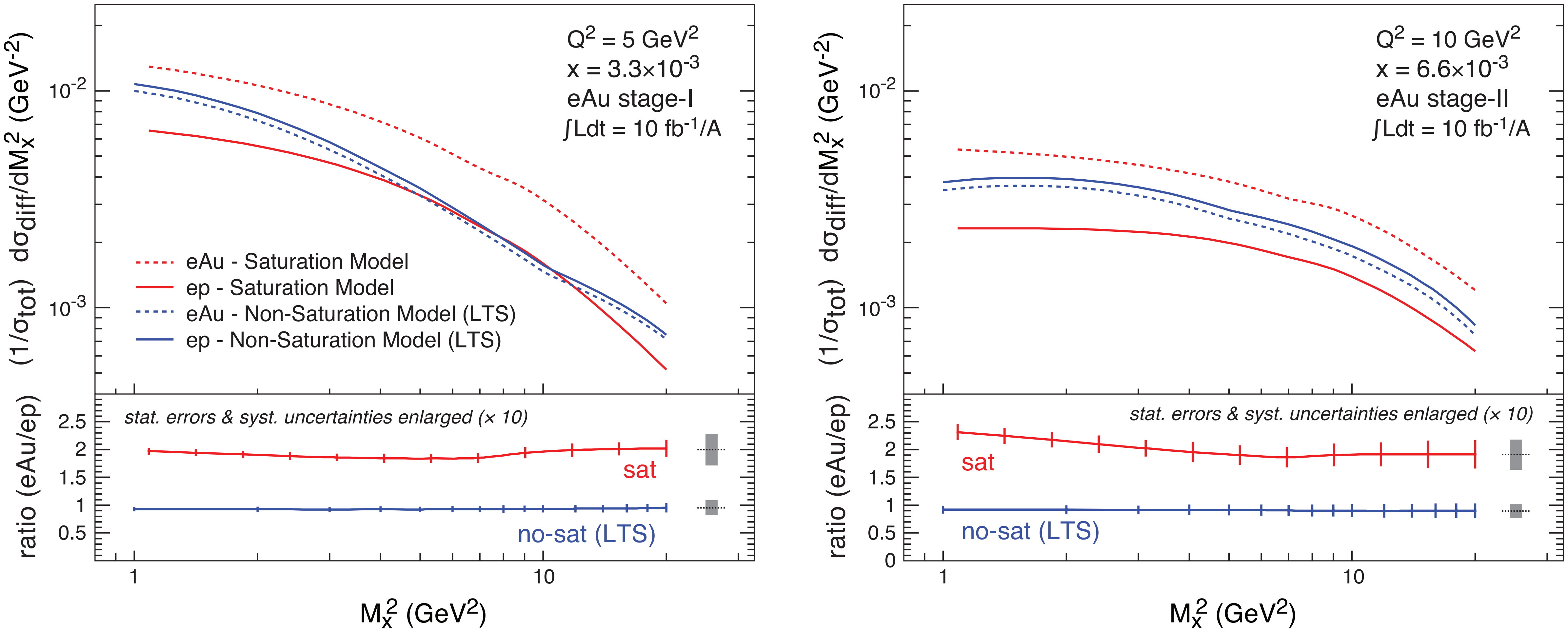
Diffraction





- Ideal tool for both
  - studying saturation
  - imaging gluons
- "**Coherent**": nucleus intact
- "**Incoherent**": nucleus breaks up (no diffraction pattern)

Diffraction: saturation

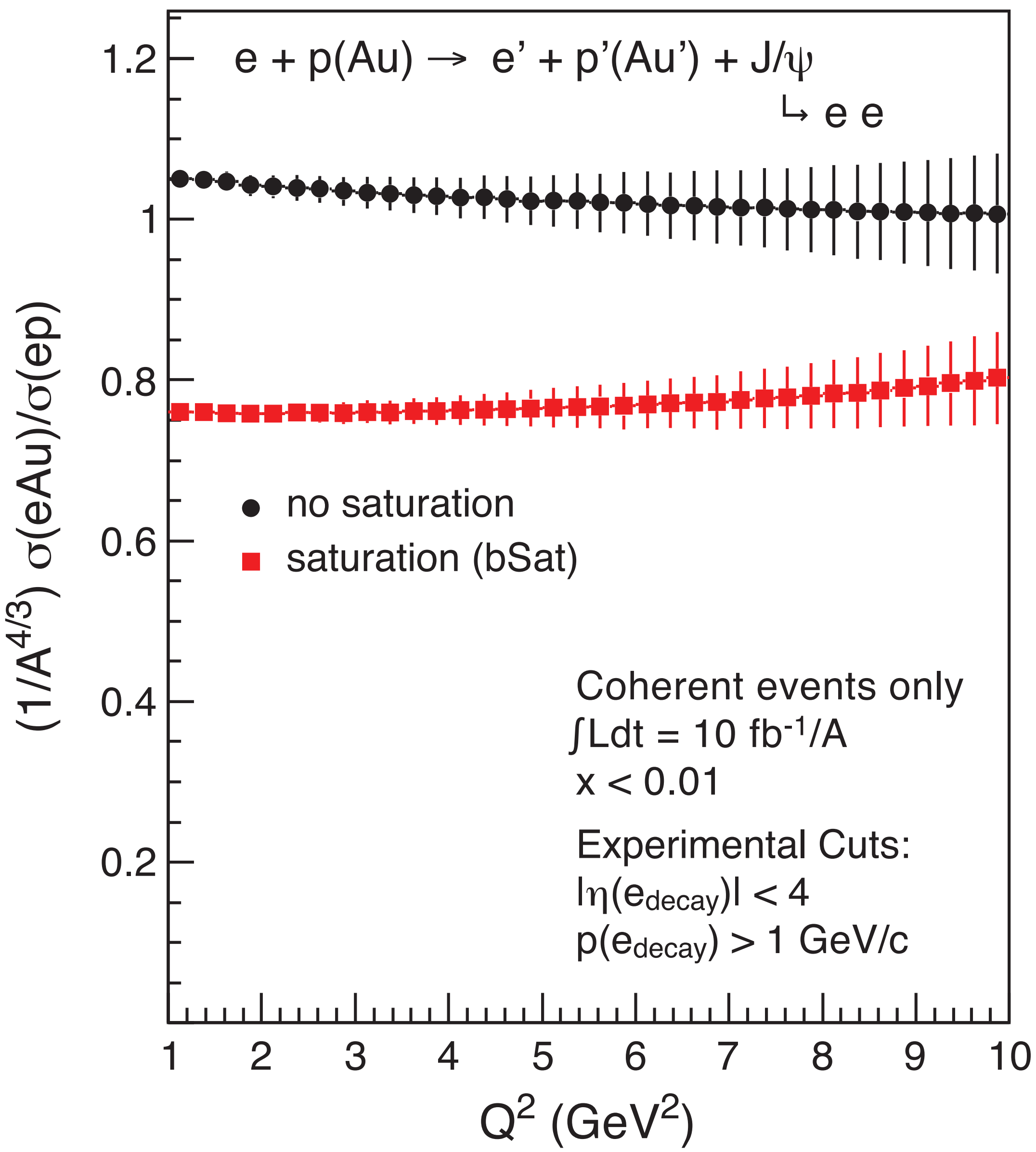


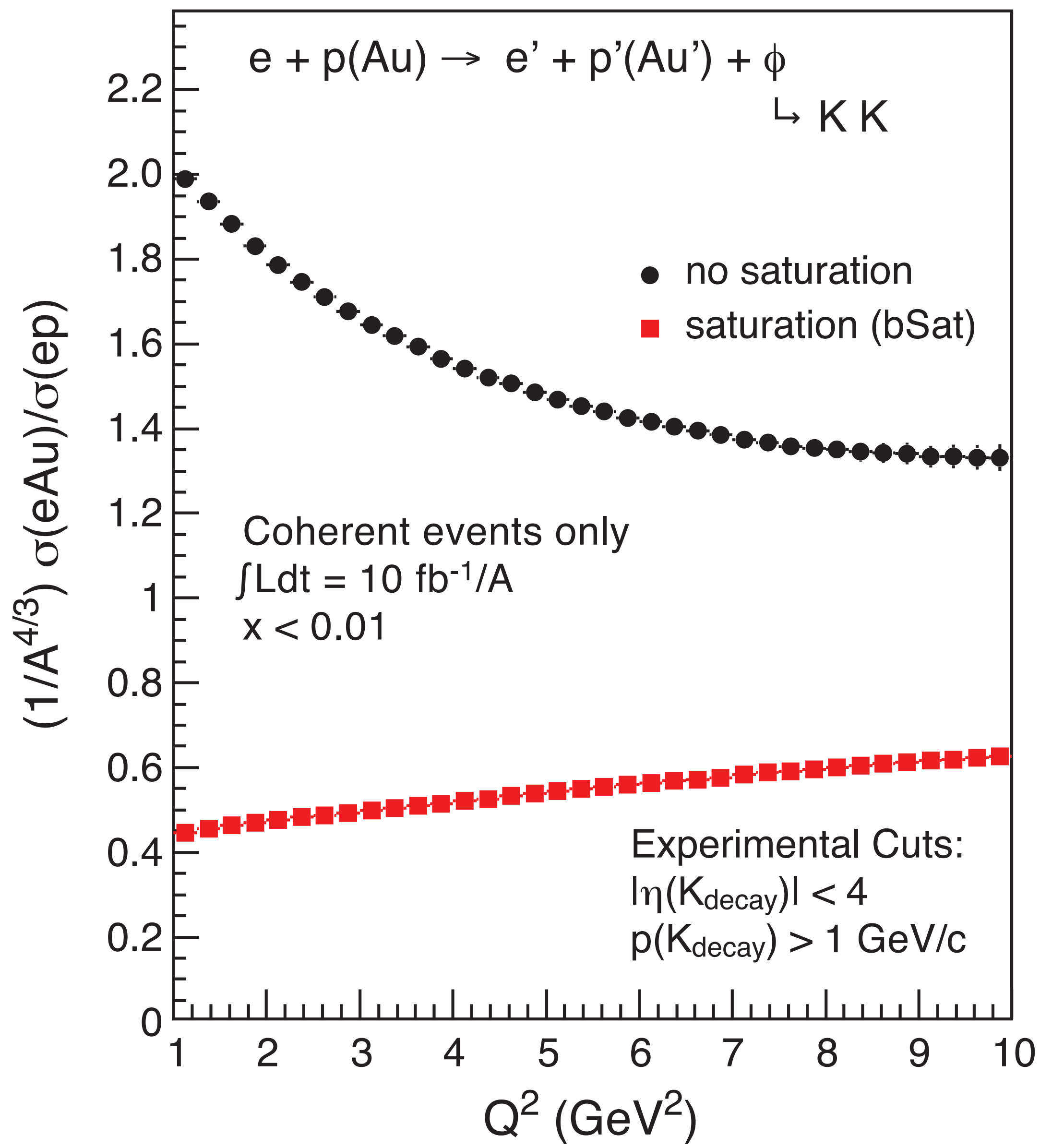
- No saturation: eA/ep ratio ~ 1
- Saturation: enhances σ_{diff} in eA vs. ep
  - strong distinguishing power at eRHIC

Exclusive vector mesons

e + A → e` + A` + **VM**

- Measure t via exclusive final state
- Clear difference between **saturated** and **unsaturated**





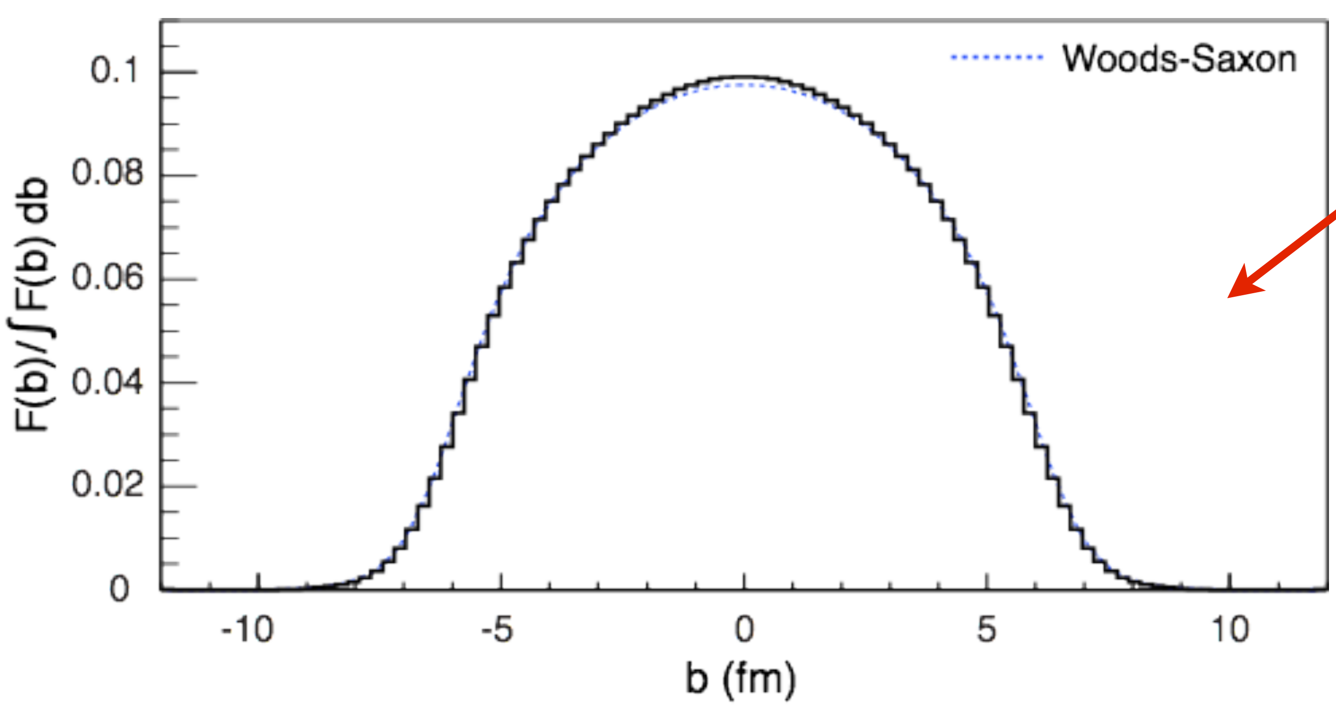
Diffraction: imaging

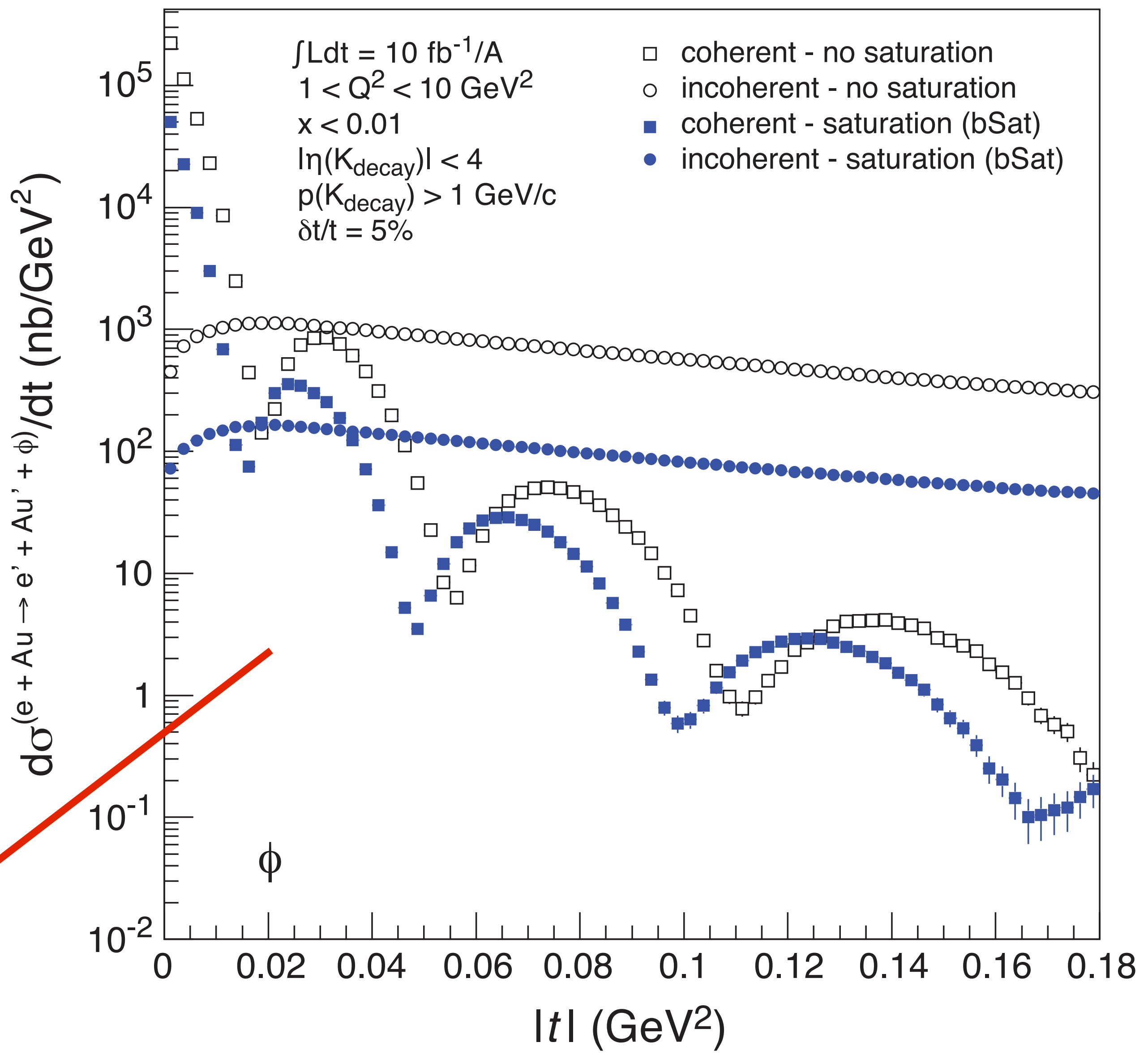
- t is conjugate of impact parameter, b

$d\sigma/dt$ ⟷ (Fourier Transform) $F(b)$

➡ gluon imaging

- Strict detector demands

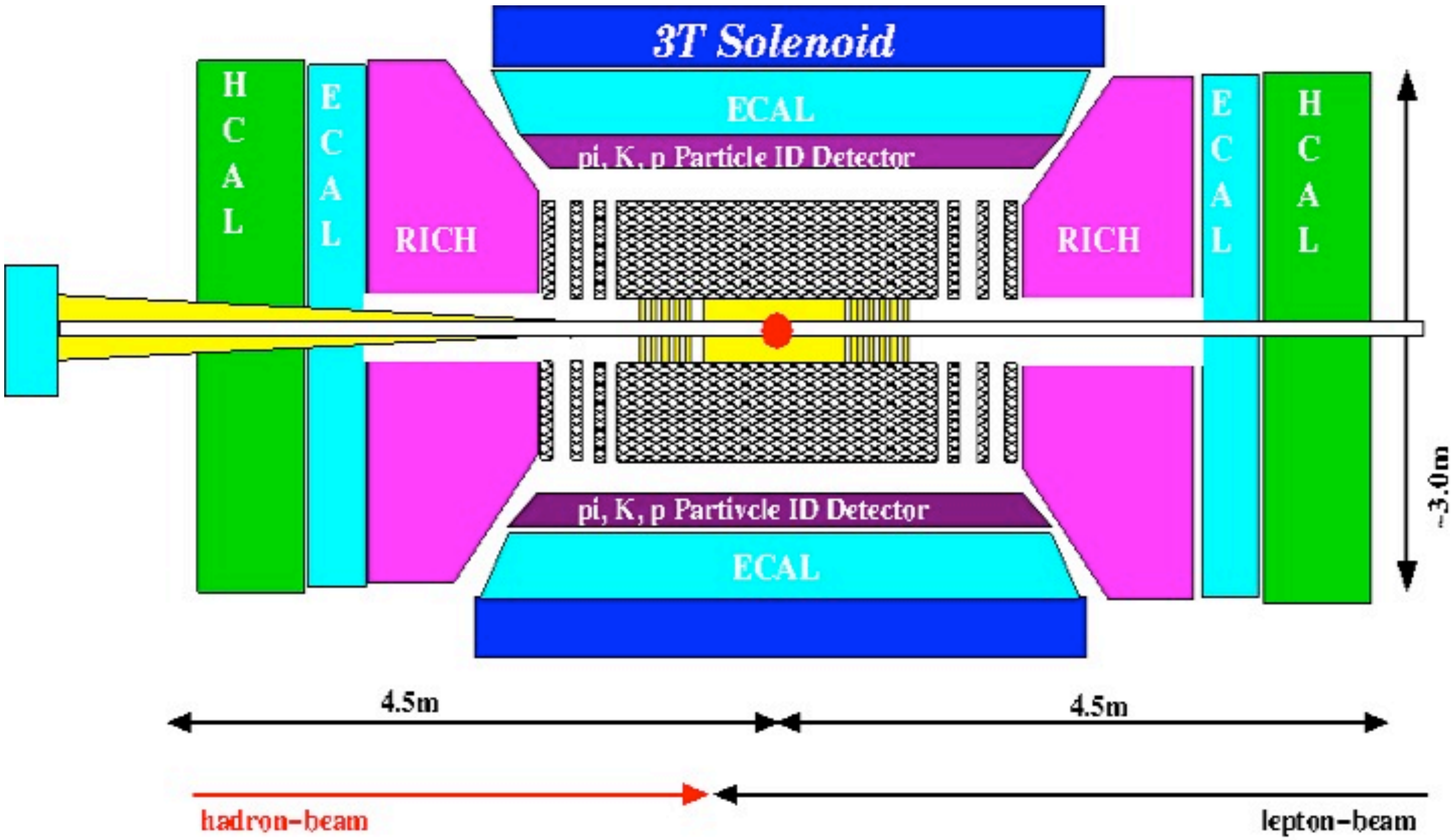




Detector and machine

Detector concept

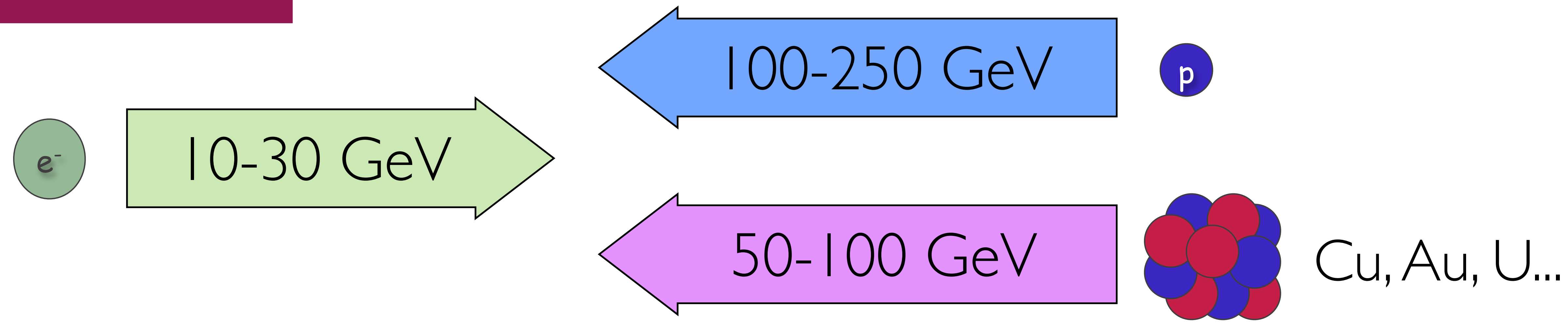
- Largely hermetic
  - needed e.g. to detect rapidity gap



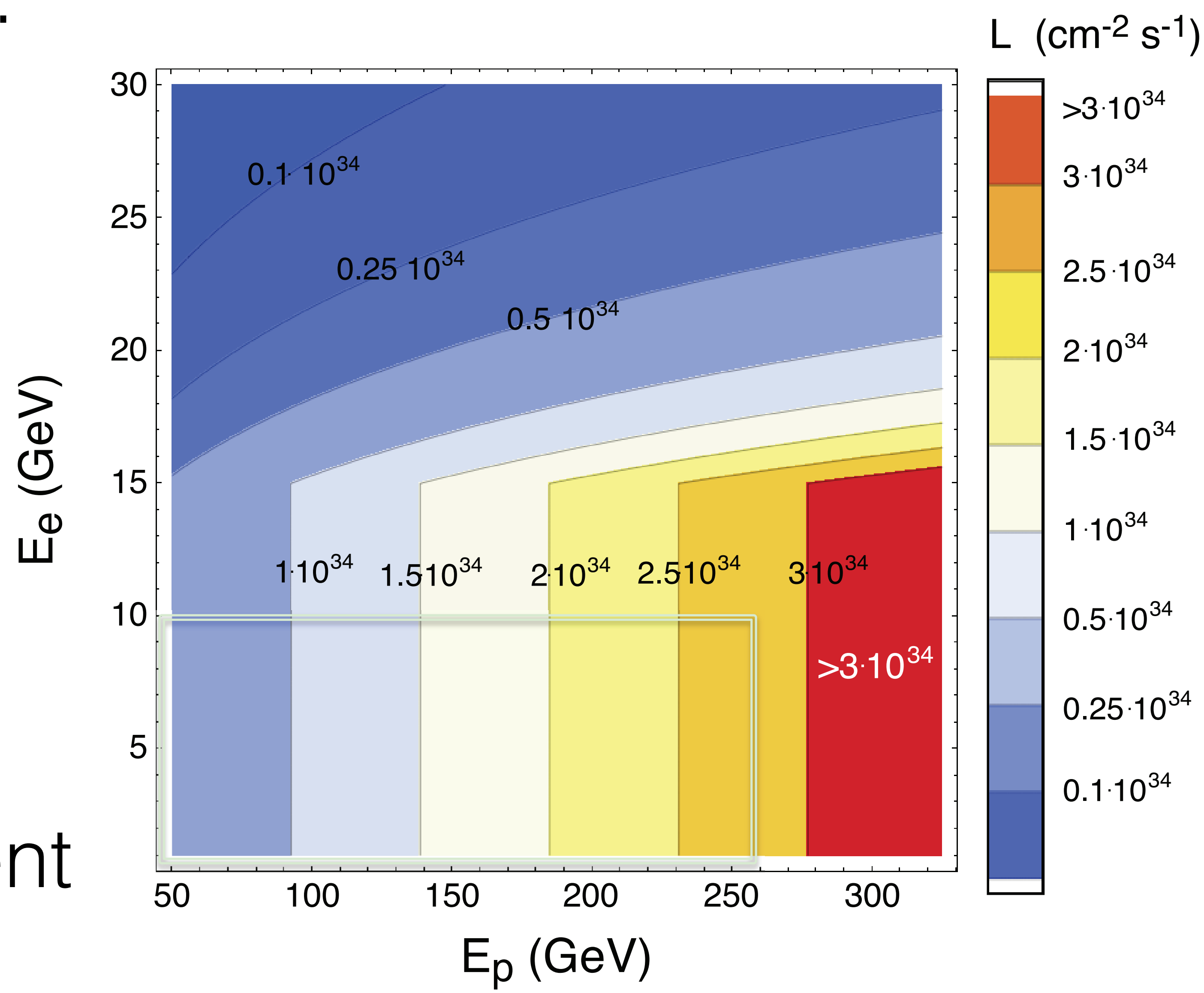
To Roman pots, ZDCs

ZDC: breakup neutrons give ~100% efficiency to detect incoherent eA

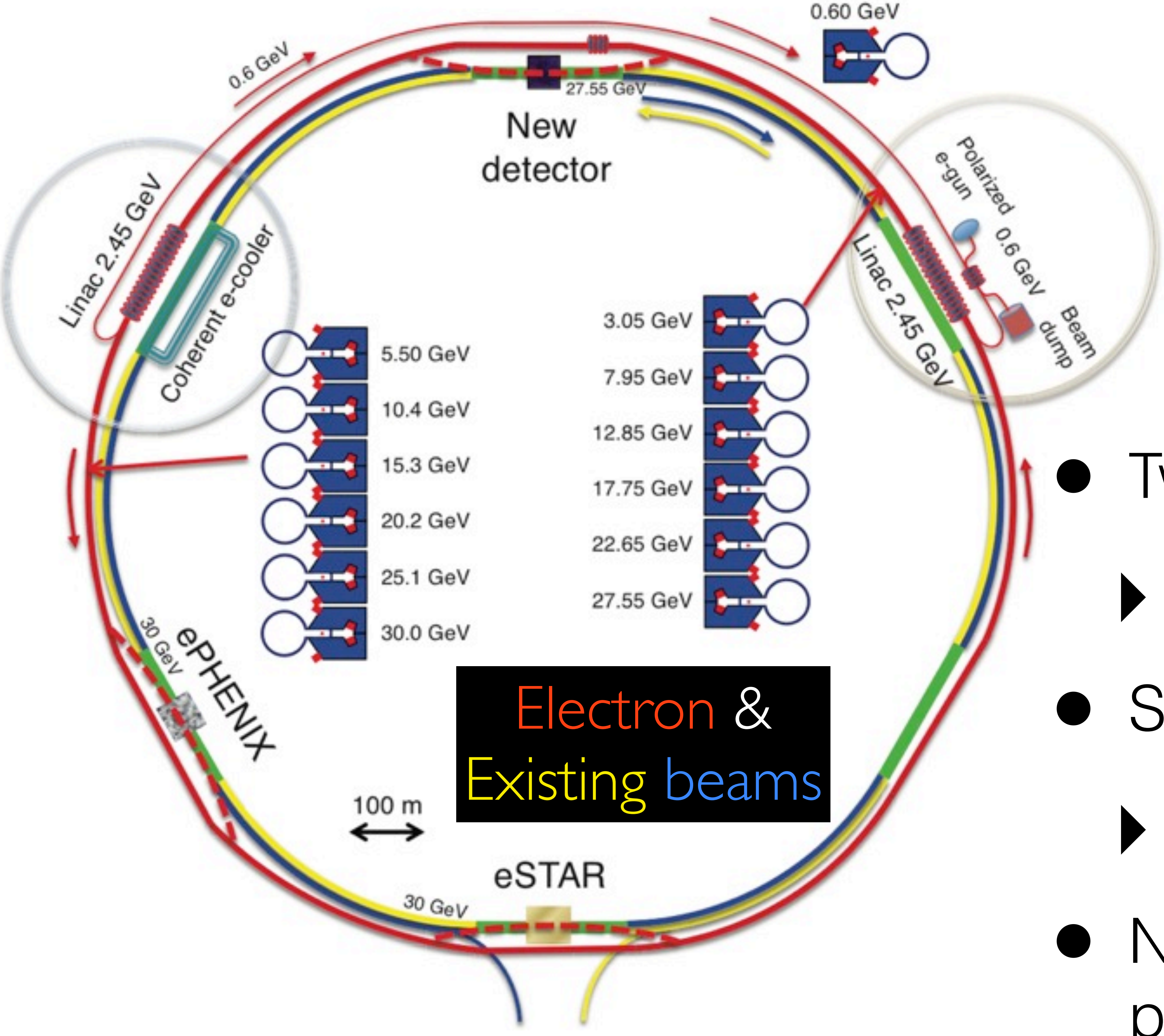
eRHIC



- **4 goals** of machine design:
  1. Variable beams **species**
  2. Variable beam **energies**
  3. High **luminosity** ~10^{34}
  4. e^- **polarisation** ~80%
- Maximise use of existing infrastructure and investment

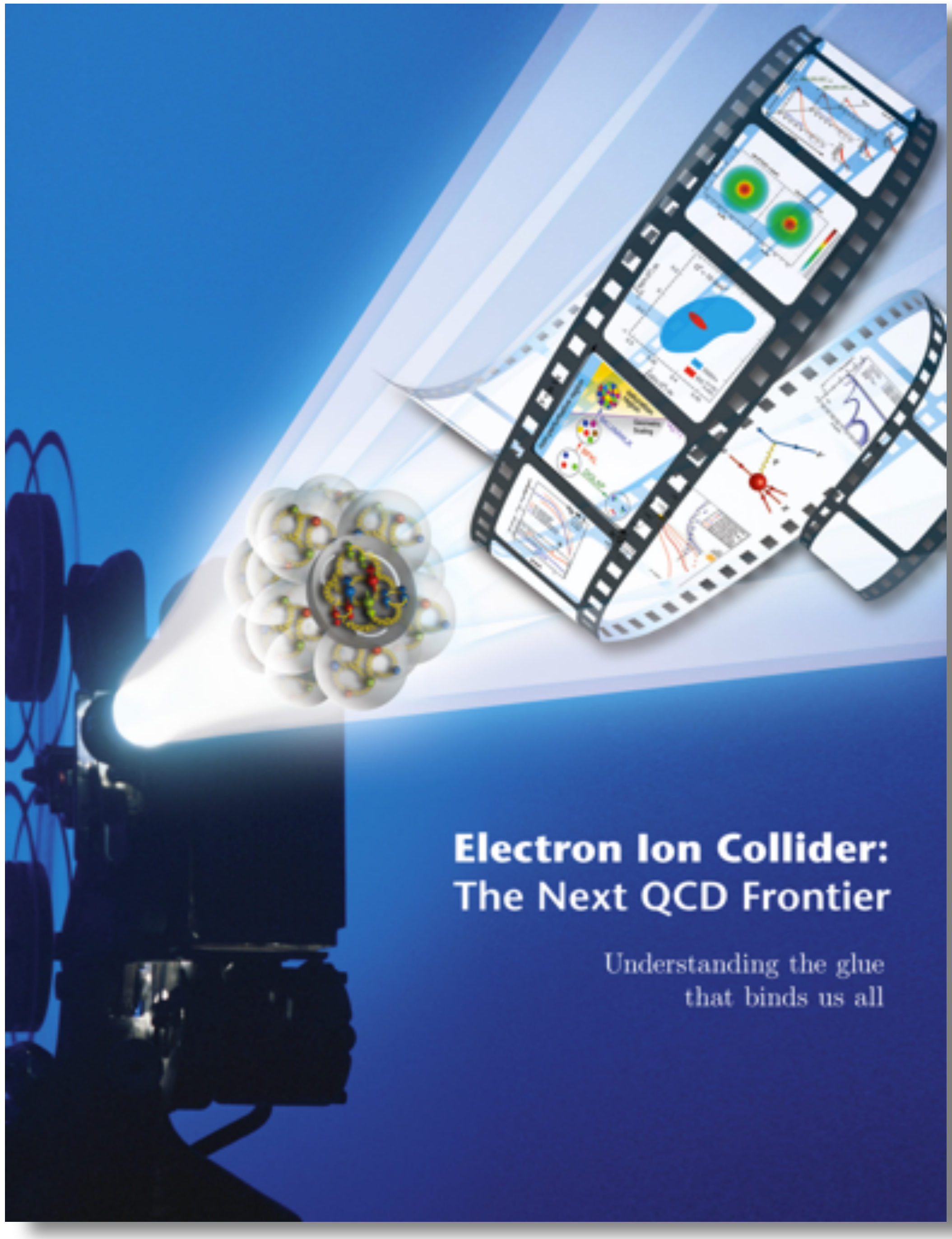


eRHIC



- Two linacs
  - multiple passes
- Stageable energy
  - add RF cavities
- New high-intensity polarised e^- source

Outro

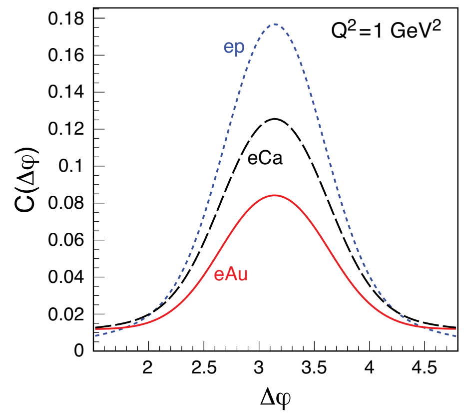


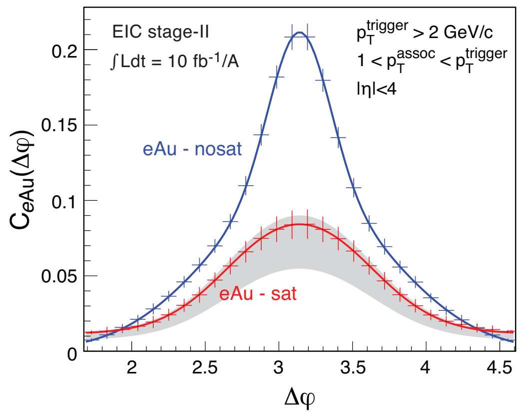
- arXiv:1212.1701
- arXiv:1108.1713
- wiki.bnl.gov/eic/index.php/Main_Page

3 signs of saturation @ eRHIC

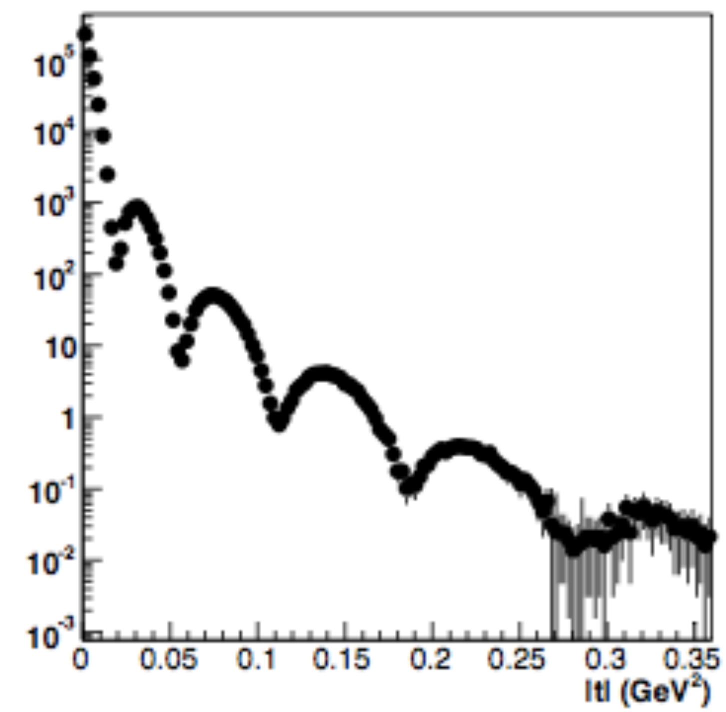
- We know saturation is interesting...
- ...and why using nuclear beams makes sense to find it
- So what do we look for?
  - Structure functions - also nPDFs
  - Dihadron correlations
  - Diffractive events - also imaging

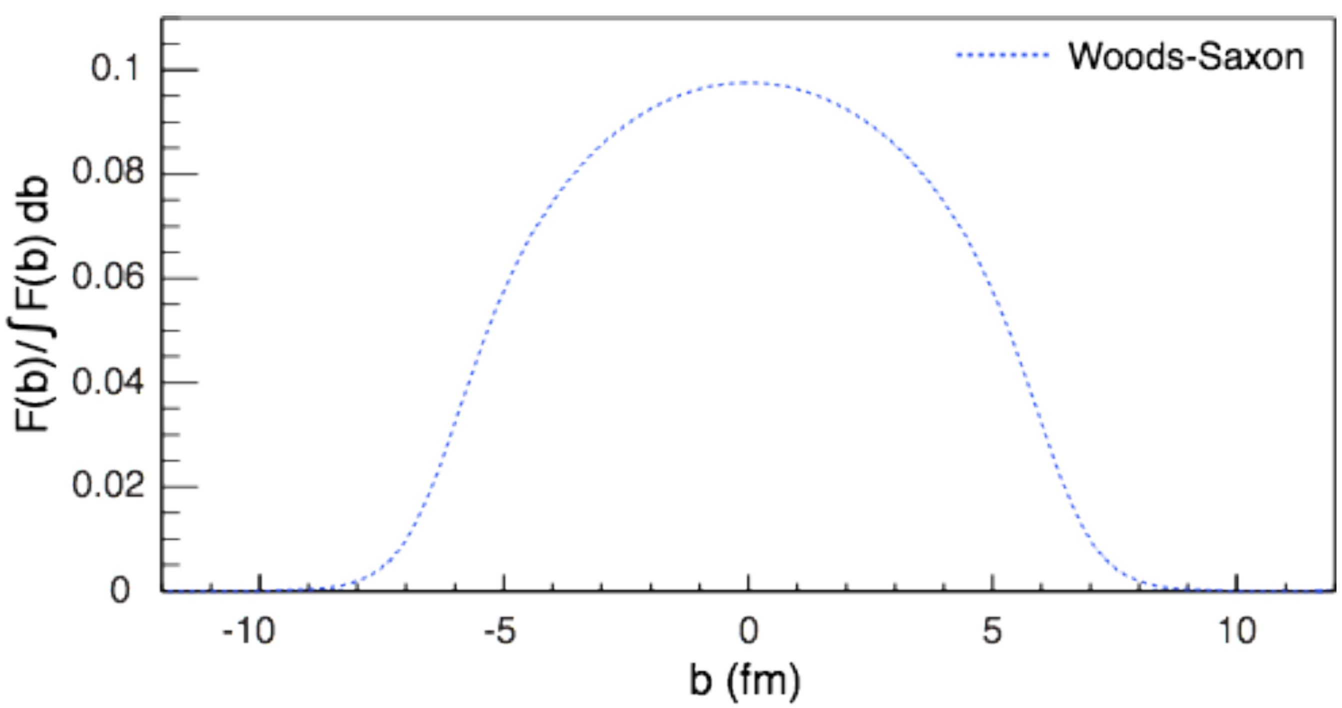
dihadron correlations

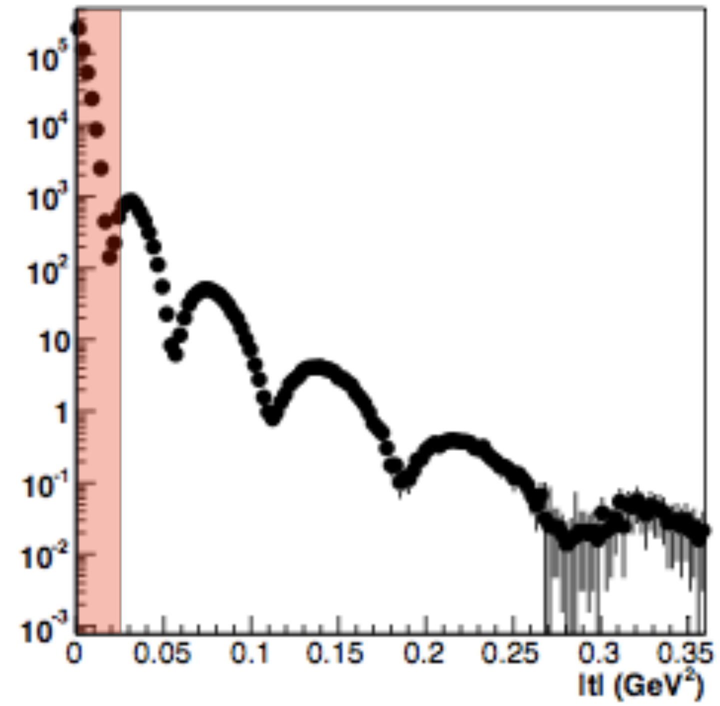




- "semi-inclusive" DIS
- multiple gluon re-scattering, emission in saturation framework washes out correlation
- ratio = 1 in absence of collective nuclear effects
- shaded: uncertainties in knowledge of saturation scale
- ep baseline needed, but cancels various uncertainties


|t| (GeV^2)


Woods-Saxon
F(b)/∫F(b) db
b (fm)



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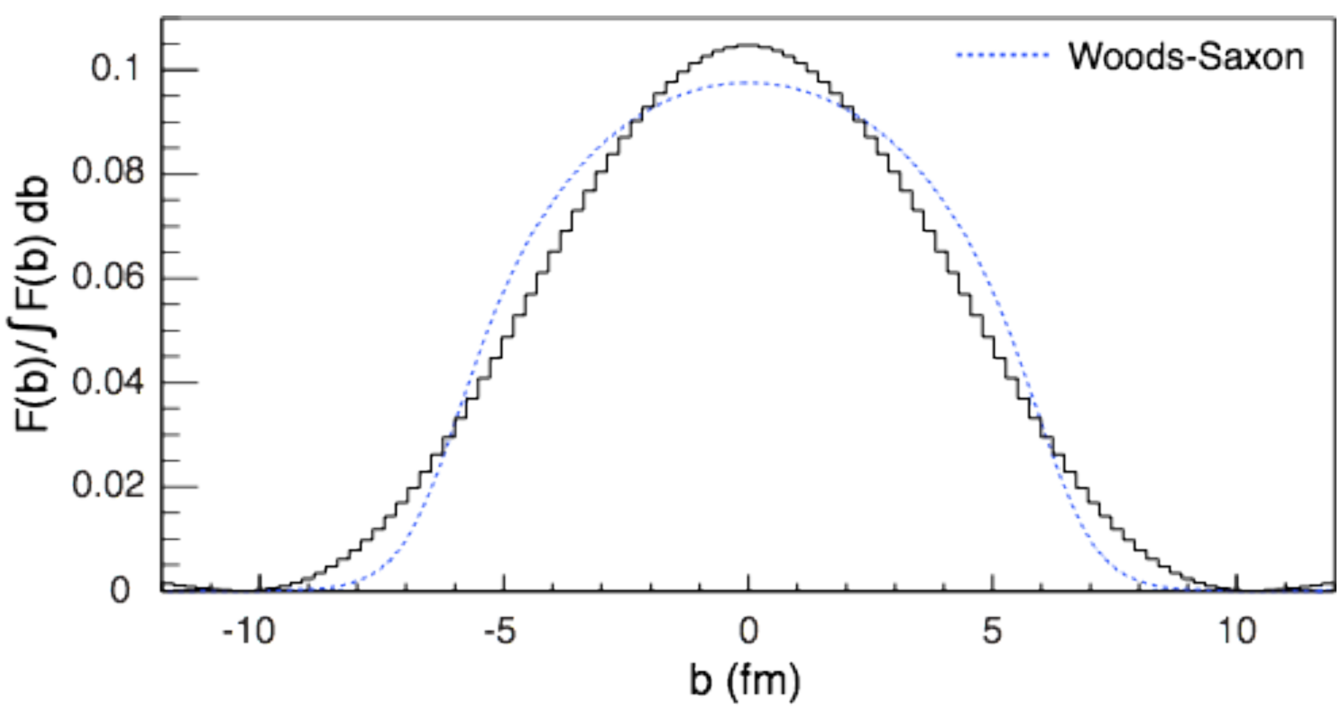

Woods-Saxon
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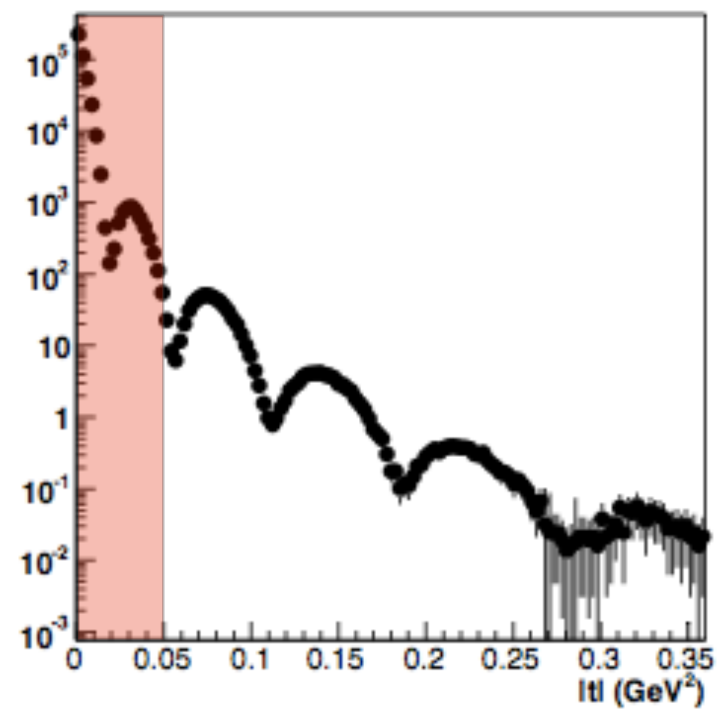

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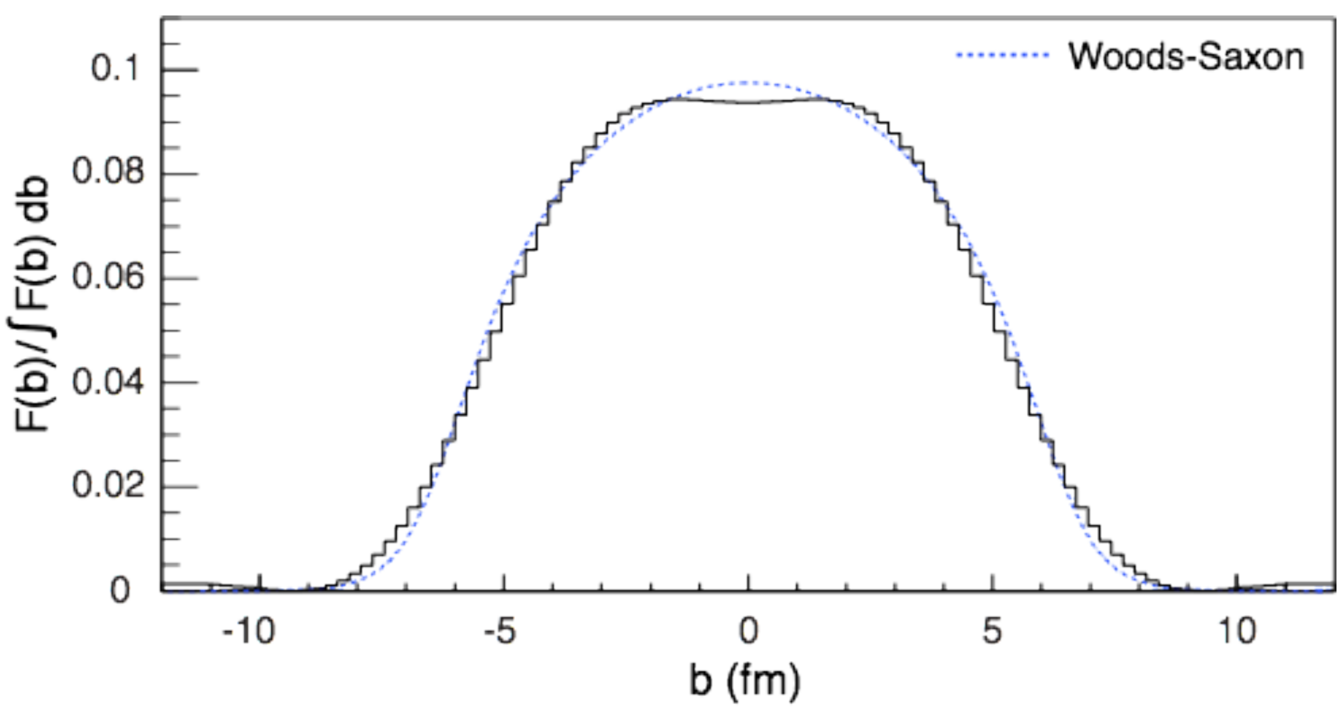

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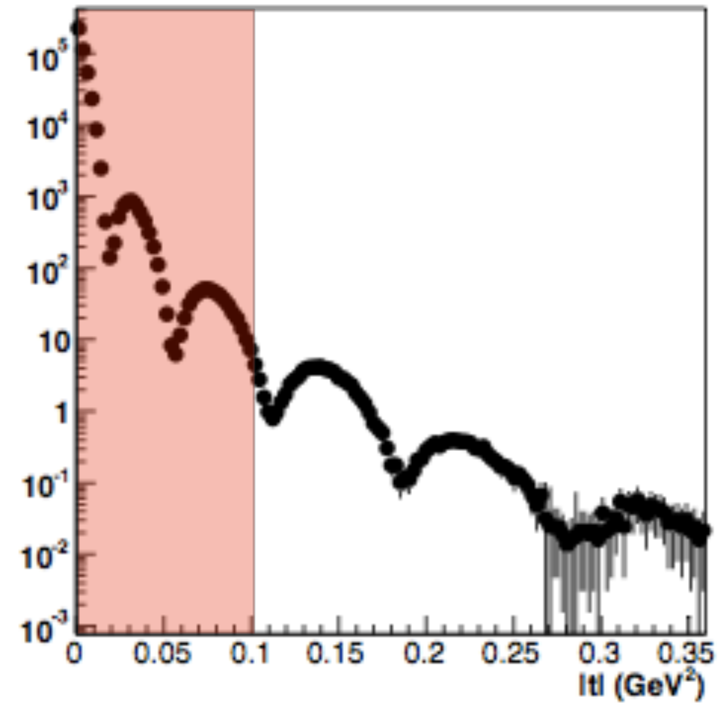

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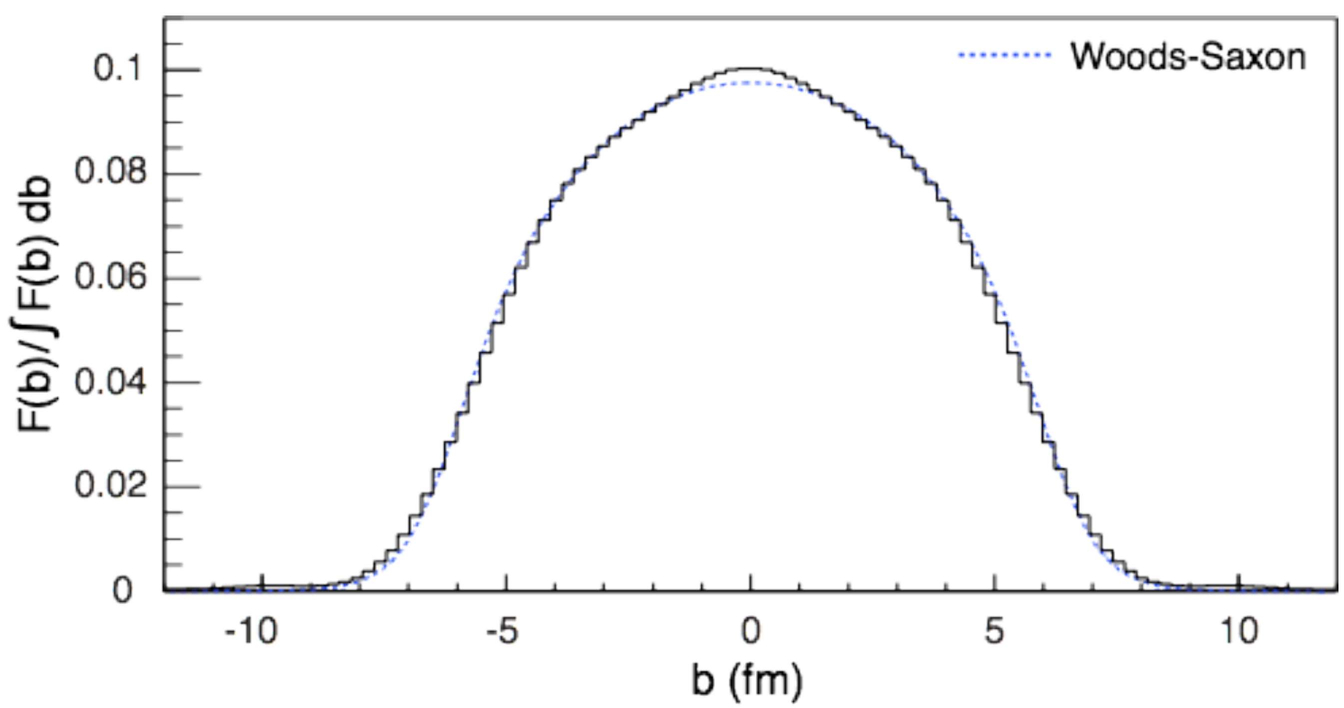

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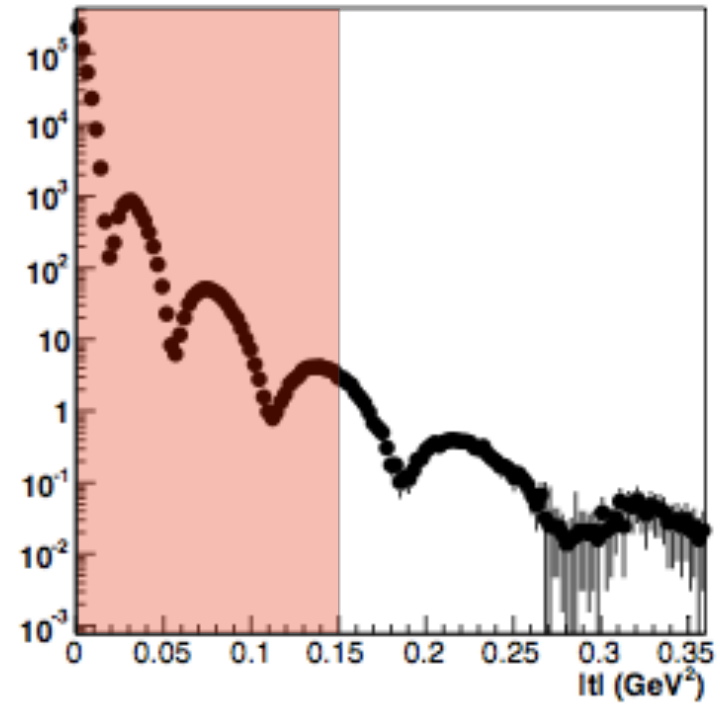

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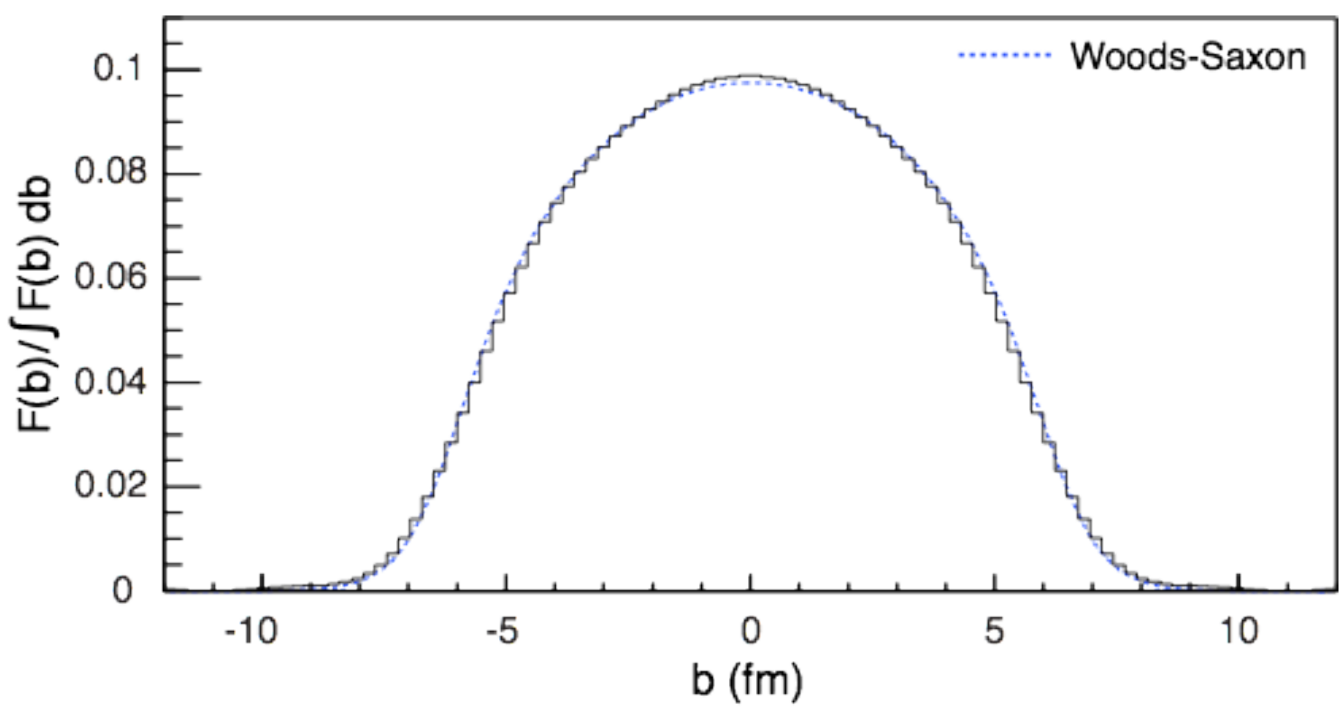

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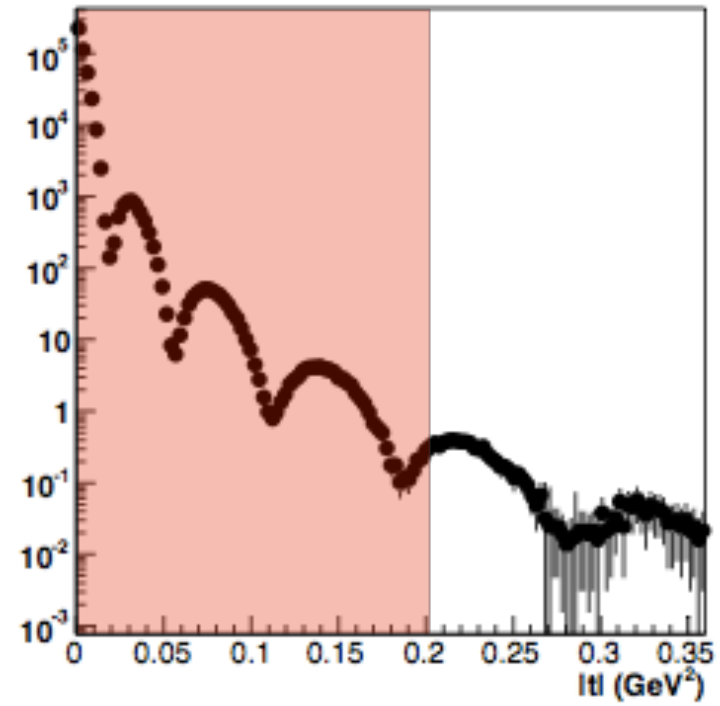
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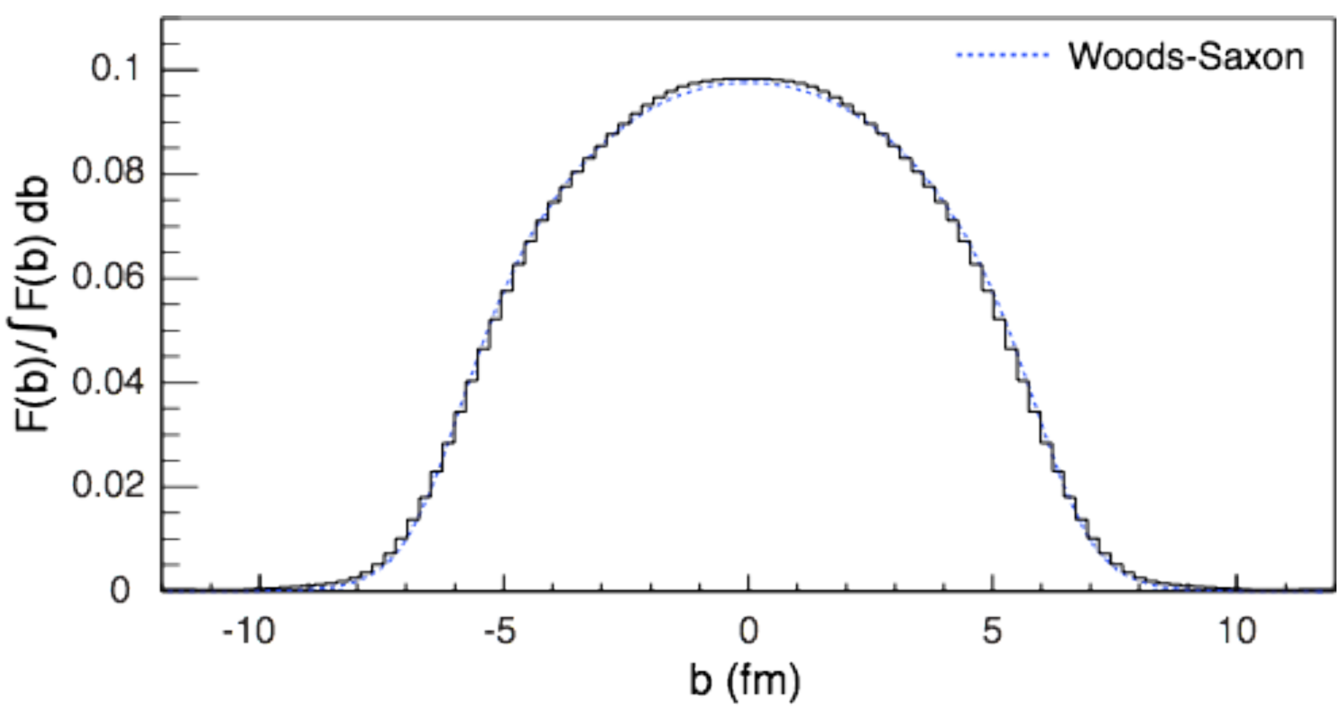
Woods-Saxon
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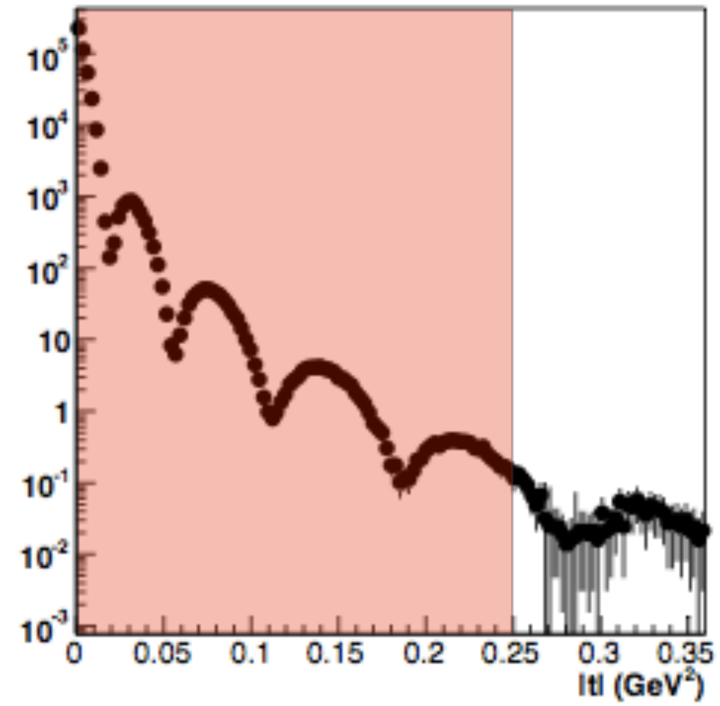
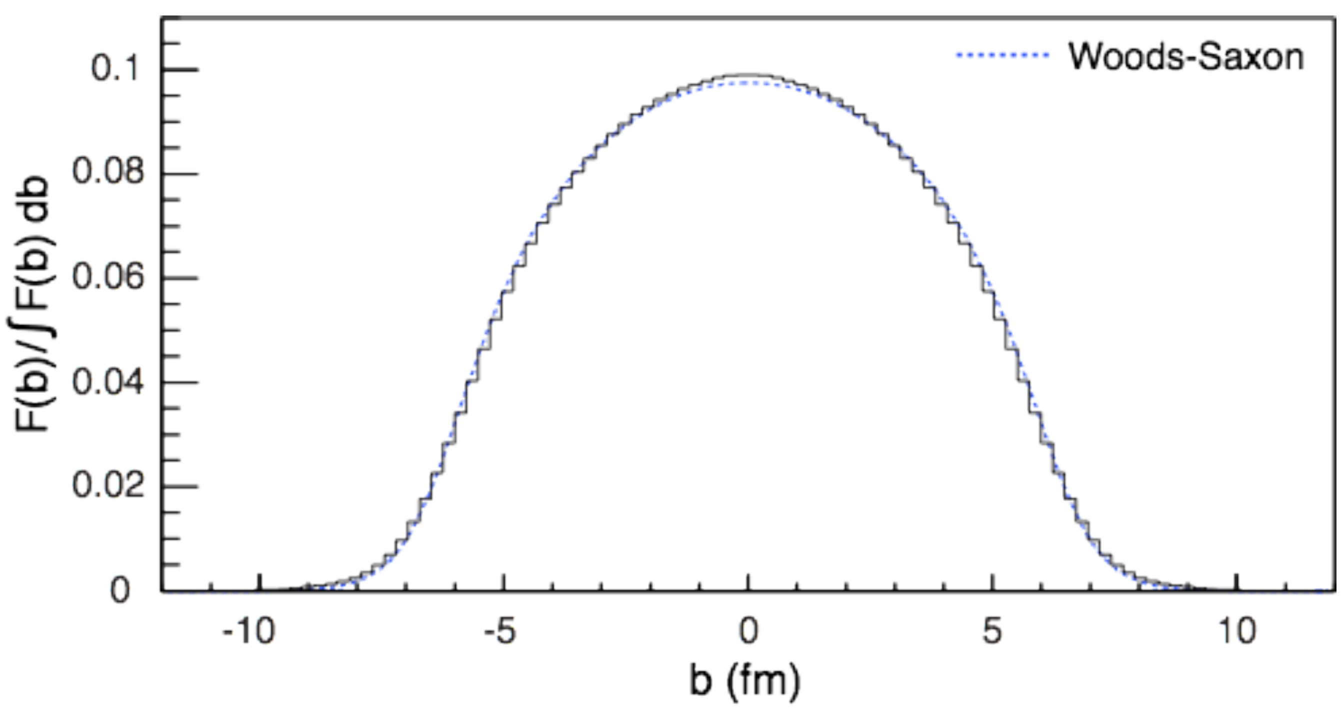

|t| (GeV^2)


Woods-Saxon
F(b)/∫F(b) db
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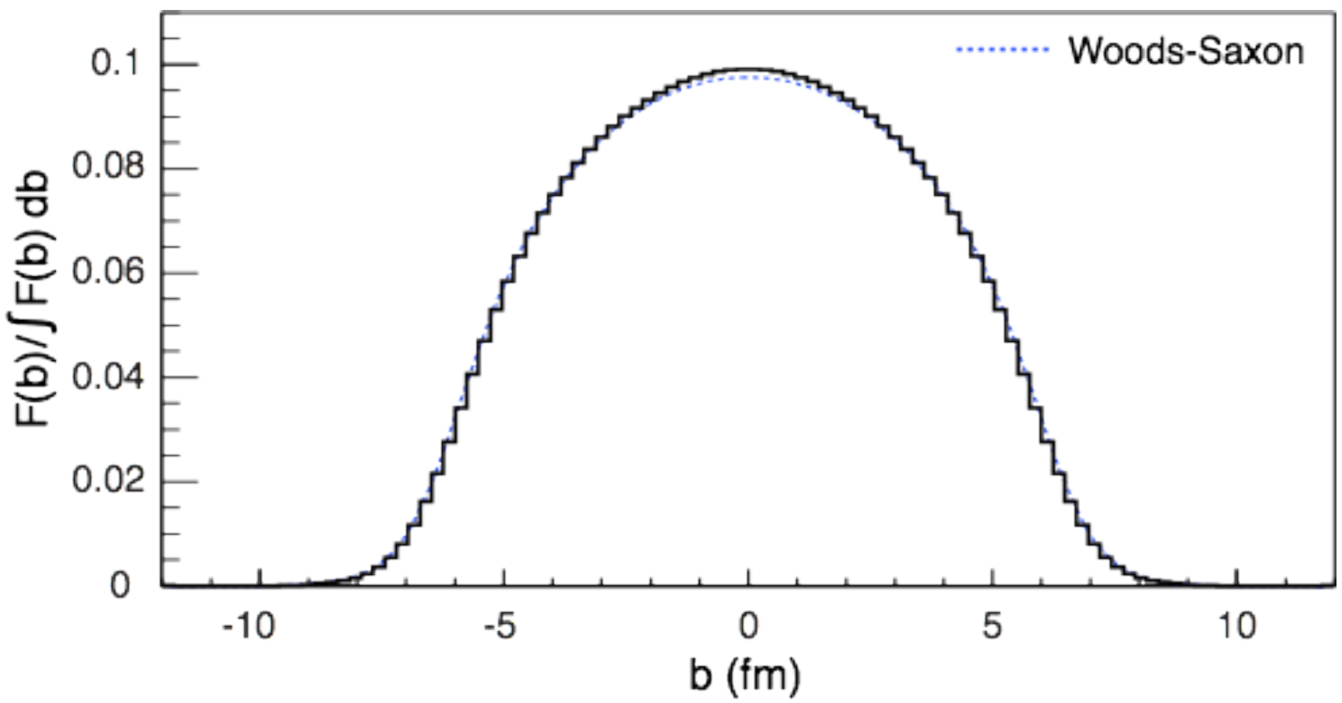

Woods-Saxon
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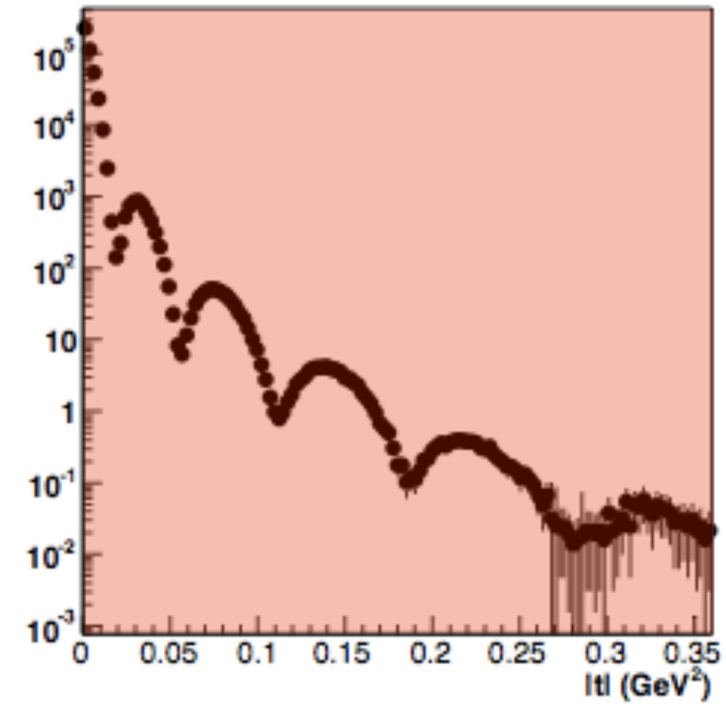

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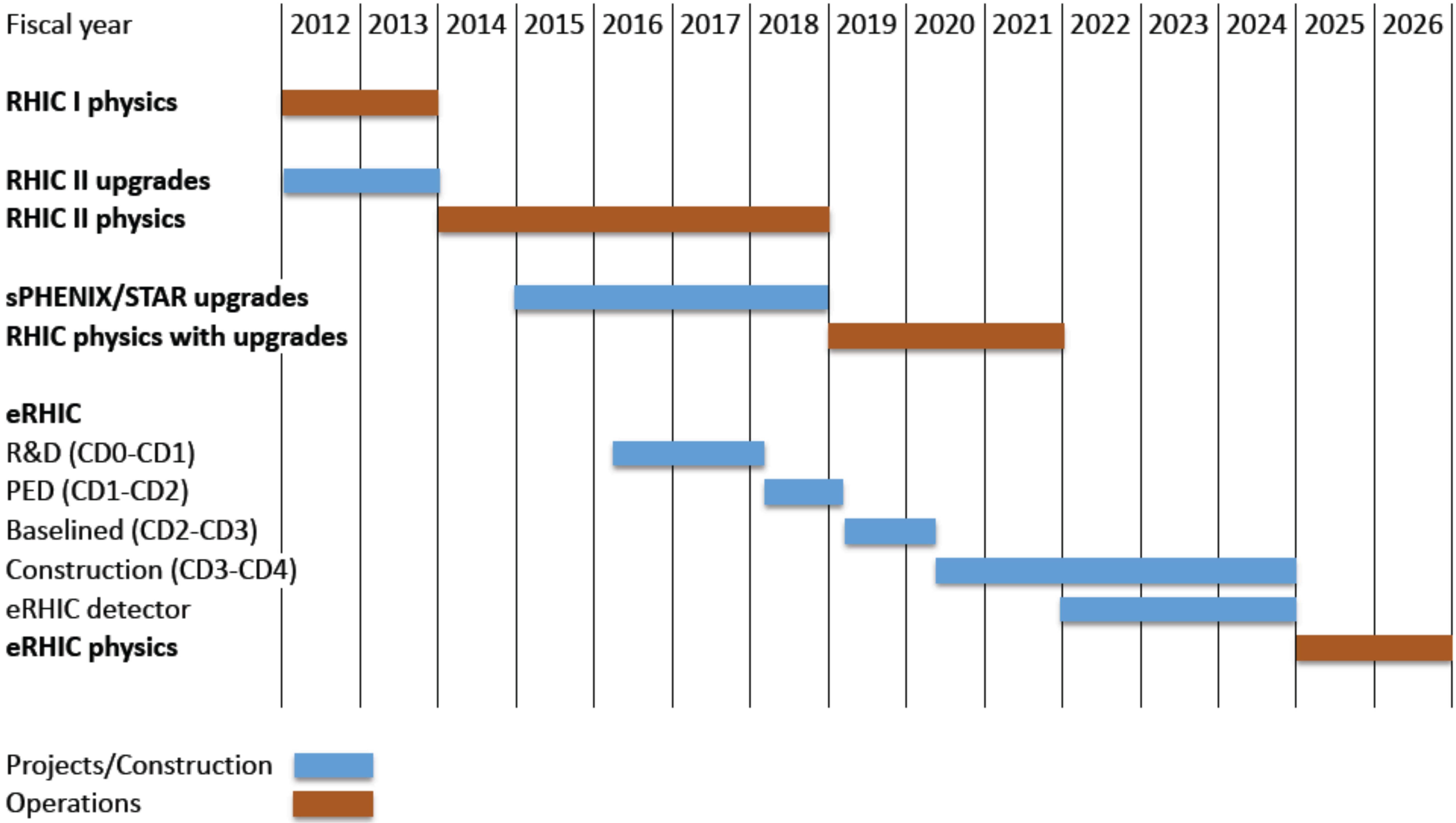
Fiscal year
2012
2013
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2023
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2025
2026
RHIC I physics
RHIC II upgrades
RHIC II physics
sPHENIX/STAR upgrades
RHIC physics with upgrades
eRHIC
R&D (CD0-CD1)
PED (CD1-CD2)
Baselined (CD2-CD3)
Construction (CD3-CD4)
eRHIC detector
eRHIC physics
Projects/Construction
Operations